GTE Sylvania

INSTRUCTION MANUAL FOR

SRL/SERIES

ID No. One + Only
– RETURN TO –
INSTRUMENT CONTROL
SYLVANIA SES -/- West

Sorensen POWER SUPPLIES

(FAN COOLED)

SORENSEN COMPANY

A UNIT OF RAYTHEON COMPANY

676 ISLAND POND ROAD MANCHESTER, NEW HAMPSHIRE 03103

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1 INTRODUCTION

1.1 PURPOSE

This manual contains operation and maintenance data on the fan-cooled SRL series power supplies. The purpose of the manual is to familiarize the user with unit functions, to introduce the varied configurations to which the unit is convertible, and to provide the necessary maintenance data to assure long operating life.

Seven major sections form the content of the manual. Section 1 contains a description of the series, highlights important unit features, and tabulates complete unit specifications. Unit inspection and initial checkout procedure is covered in Section 2, and unit operation procedures are outlined in Section 3. Section 4 details the unit theory of operation, and Section 5 provides maintenance, service and repair instructions. Unit schematics, parts lists and operating curves and waveforms are included in Section 6, and accessory data (where applicable) and unit warranty is found in Section 7.

1.2 DESCRIPTION

The fan-cooled series consists of seven models in the 500 to 2KW range with outputs ranging to 60 Vdc. Differences in models are noted as applicable.

1.2.1. Physical

SRL power supplies are designed for either bench-or rack-mounted use, and for easy component accessibility. All controls used in normal operation are mounted on the front panel (see Figure 1-1, and Table 1-1). Power outputs up to 25 amperes may be taken from the unit front-mounted binding posts. The mode selector terminal board is at the rear of the supply. Through manipulation of the terminal board links, the functions of voltage/current mode programming, remote sensing and parallel operation are obtained. Output terminals are provided at the rear of the SRL series units.

Units provided in the fan-cooled series include models 10-50, 10-100, 20-50, 40-25, 40-60, 60-17 and 60-35.

TABLE 1-1 SRL PANEL CONTROLS/INDICATORS

Control	Function
POWER Light (DS1)	Illuminates when POWER switch is in the ON position. (And internal fuse is not blown)
OVERVOLTAGE SET (S2)	Momentary toggle switch, when depressed causes panel dc VOLTS meter to indicate overvoltage trip level.
OVERVOLTAGE ADJ (R85)	Recessed potentiometer to adjust trip level of overvoltage circuit.
OVERVOLTAGE INDICATOR (DS2)	Illuminates when limit set by OVERVOLTAGE ADJ (R85) has been exceeded by the power supply output voltage.
DC VOLTS Meter (M1)	Provides direct readout of voltage selected by voltage controls.
DC AMPERES Meter (M2)	Provides direct readout of load current.
CURRENT Controls (R18A), (R18B)	Provide coarse and fine adjustment of output current. (Current Mode)
VOLTAGE Controls (53A, R53B)	Provide coarse and fine adjustment of output voltage. (Voltage Mode)
THERMAL OVERLOAD (DS3)	Illuminates when unit temperature exceeds a preset limit.
POWER Switch (CB1)	Applies ac line voltage to input of power supply.

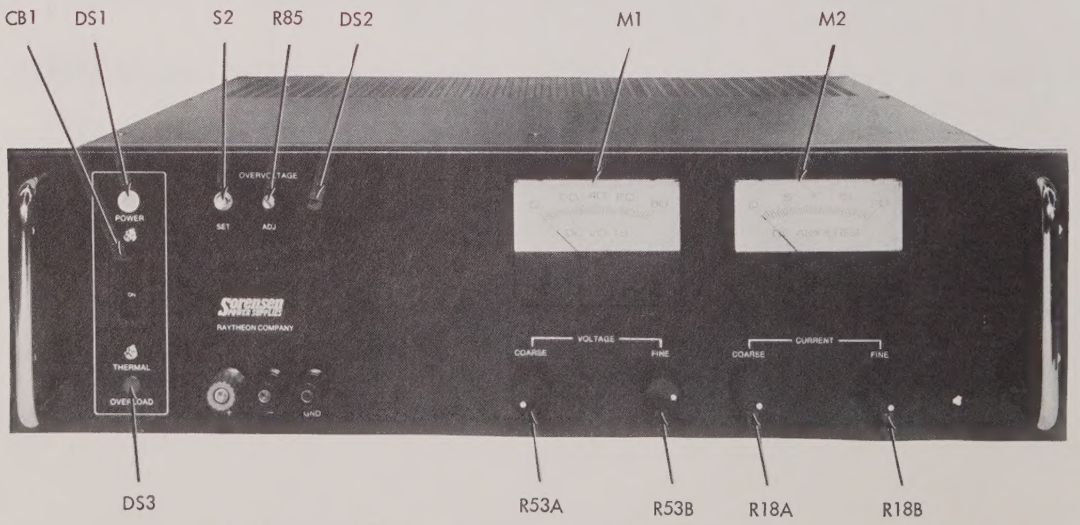


FIGURE 1-1. FRONT PANEL CONTROLS AND INDICATORS (TYPICAL)

TIPS ON VERIFYING SPECIFICATIONS

A high performance power supply such as this unit requires careful testing if a true evaluation of its performance is to be made. The following general rules pertaining to measurements are given to preclude the rejection of this supply based on data obtained using incorrect test methods.

1. Connect all test instruments at the power-supply sensing terminals, not at the load. Connect the load to the load terminals.

   Erroneous readings can be obtained if measurements are taken at the load, and may be illustrated by an example: Consider a 10 V, 1A unit with a specified load regulation of ±0.01%, (±1.0 mV). With the output set to 10 V, the voltage deviation could be 2 mV. But this is at the supply terminals. Just 1 foot of No. 23 load-lead wire is sufficient to drop 16 mV (eight times the maximum deviation permitted by the regulation specifications). Results from a test setup of this kind would, of course, be invalid.

   Another not-so-obvious example of the same problem is encountered when measurements are made at binding-post terminals instead of the barrier-type "sense" terminals. The binding posts may introduce a resistance between the test leads and the regulated (sensed) output points. The resistance results in a voltage drop which is subtracted from the output voltage before measurement. It therefore has the same effect as load leads. Figure A gives electrical and mechanical representations of a binding post and its unregulated voltage drop. Note that the same problem may be encountered when the load leads are connected to the sense terminals. (Figure B illustrates correct load-lead location).

2. Use twisted wire or coaxial cable for test leads.

   Stray pickup can substantially influence the extremely small deviations being measured.

3. Terminate test leads with solder or spade-type lugs.

   Alligator clips or other similar connectors may introduce undesirable contact resistances and result in false readings.

4. After connecting the test system, check for system-generated noise and ripple.

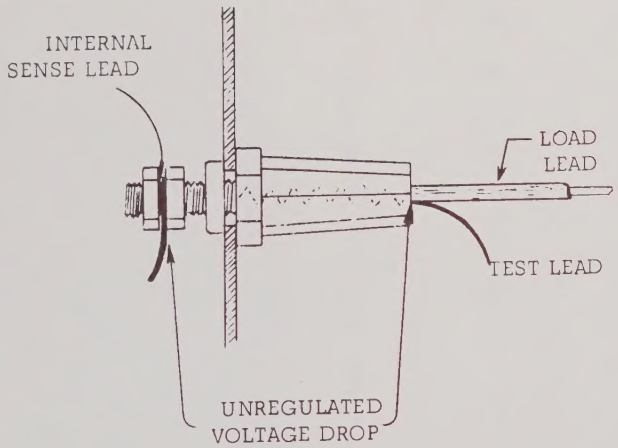
   Ground loops occasionally introduce noise and ripple not related to the power supply performance.

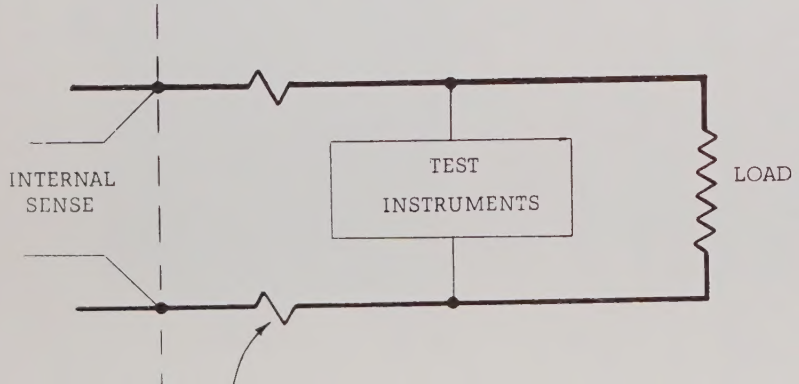
5. Refer to testing information provided in your instruction manual before attempting any measurements.

RAYTHEON COMPANY-SORENSEN POWER SUPPLIES
676 Island Pond Road
Manchester, New Hampshire 03103

No. A14-6694

FIGURE A





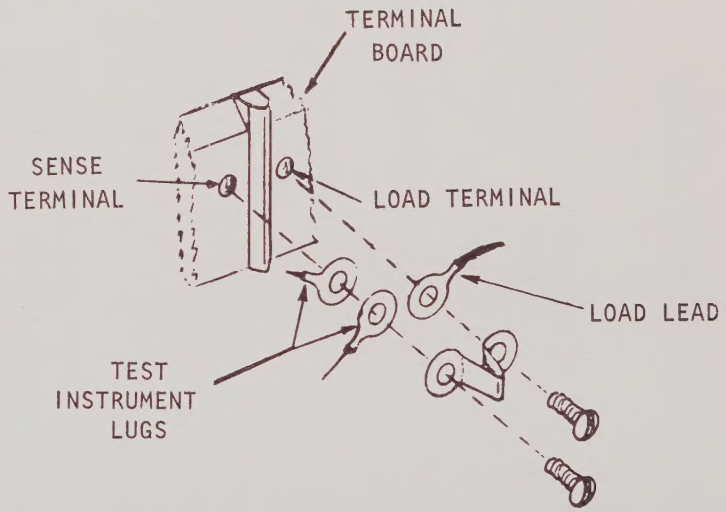


FIGURE B

1.2.2 Functional

The SRL power supplies provide a precisely regulated dc output, adjustable over a wide range. They operate from any of three*nominal ac inputs, and exhibit rapid response to transients, both load and line. Unit characteristics are outlined in specifications table 1-2.

All semiconductors used in the SRL series are silicon types, and contribute significantly to the unit ambient-temperature characteristics. High dissipation transistors are mounted to a cast aluminum alloy heatsink; low-dissipation devices are located on a plug-in printed circuit board.

1.2.2.1 Operating Modes

SRL models have two basic operating modes; constant voltage and constant current. In the former, the output voltage is regulated at the front-panel selected or programmed value, and the output current varies with the load. In constant-current operation, the output-current is regulated at the selected value while the output voltage varies as a function of load.

1.2.2.2 Automatic Crossover

The automatic crossover capability enables the unit to transfer operating modes as a function of load requirements. If, for example, load current attempts to increase above the setting of the current adjust control, the unit will switch operation automatically from the voltage to current mode. If the load requirements are lowered, return to the voltage mode will occur automatically.

1.2.2.3 Remote Programming

Any SRL model may be remotely programmed, that is its output may be altered from a distant location in either the voltage or current mode by introducing a calculated resistance or signal into the appropriate programming circuit. This may be readily accomplished through the link arrangements at the rear terminal board.

1.2.2.4 Remote Sensing

Terminals located on the rear terminal board offer the means of extending a unit's regulating point from the output terminals to the load. This, in effect, compensates for variations in the load-lead IR drop. The maximum drop for which a unit will compensate is 1 volt per load-lead.

1.2.2.5 Series Operation

For applications requiring voltages higher than a single SRL can provide, a number of units may be connected in series. Maximum system output is specified at 200 Vdc. Unit connections are illustrated in Section 3 (figure 3-3). Regulation in series operation is the sum of the regulations for all units. In series operation, external rectifiers to protect units against reverse voltage developed by a unit malfunction are unnecessary. Reverse-voltage protection is designed into the unit.

*Two are optional

1.2.2.6 Parallel Operation

Parallel operation may be used to service those applications requiring a higher output current than a single SRL can provide. Unit connections are illustrated in Section 3 (Figure 3-4). Paralleling is indirect through a "master-slave" approach, i.e., the amplifier of the "master" unit controls the output of all units in the system. In parallel operation, the maximum output current of each unit is derated to 90%. (See Figure 6-4).

1.2.2.7 Protection Features

Protection against the effects of overloads and internal short circuits is provided; in the first case, by automatic crossover, and in the second by the input fuse or circuit breaker. In addition,open sensing leads or links will not drive the unit into high output voltage. Internal rectifiers preclude this by clamping the output to approximately 1-1/2 volts above output setting.

Internal control circuitry is protected by fuse F2, connected in the primary of input transformer T2.

Fan-cooled units are additionally protected by a thermostatic control circuit to automatically shut the unit down in the event of thermal overload.

Table 1-2 Unit Specifications (Sheet 1 of 6)

	ALL	10-50	40-25	60-17	10-100	20-50	40-50	60-35
INPUT RATINGS								
Voltage Range	105-125/190-230/210-250						*	*
Frequency	47-53/57-63Hz							
Phase	1							
Current (Adc Max)								
@ 115Vac		14.7	22	22	32.5	28	N/A	N/A
@ 210Vac		8	12	12	18.5	15.4	25	26
@ 230Vac		7.3	11	11	16.3	14	23	24
Power Factor (typical)		0.73	0.675	0.685	0.66	0.64	0.66	0.6
Efficiency (typ)		42.4%	59.7%	61.7%	45.5%	53.6%	62.5%	67.8%
OUTPUT RATINGS								
Voltage Mode:								
Voltage Range (Vdc)		0-10	0-40	0-60	0-10	0-20	0-40	0-60
Coarse	Full Range							
Fine	1% of Full Range							
Resolution (typ)	0.01% of Full Range							
Current Range (Adc)								
@ 55°C	0-Io Max. :	0-50	0-25	0-17	0-100	0-50	0-50	0-35
@ 71°C	0-67% Io Max.							
Current Mode:								
Current Range:	Same as in Voltage Mode							

*105 - 125-volt input not provided.

Table 1-2 Unit Specifications (Sheet 2 of 6)

	ALL	10-50	40-25	60-17	10-100	20-50	40-50	60-35
Current Range (cont)								
Coarse	Full Range							
Fine	1% of Full Range							
Resolution (typ)	0.015% of Full Range							
Voltage Compliance	Full Voltage Range							
Crossover Characteristics	Figure 6-6 (Section 6)							
PERFORMANCE								
Voltage Mode:								
Regulation[1]	The greater of 0.01% or 2mV							
PARD (ripple) 50-60Hz input:[2]								
Max. RMS, 10Hz-7MHz (uV)		300	500	500	300	500	700	700
Max. P-P, 0-25MHz (mV, grounded output)		25	40	25	20	40	40	40
Transient Response (typ. recovery time-uSec)[3]	150 uSec							
Output Impedance								
Typical	Figure 6-5 (Section 6)							
Low Freq. (R & jwL):								
R=(uOhms)		10	80	180	5	20	40	85
L=(uHy)		0.5	1.2	1.6	0.3	1.6	0.8	1.6
Temp. Coefficient	0.01% +200 uV/°C							

[1]For a combined full line swing, and a NL-FL (no load-to-full) or FL-NL change.
[2]With chassis input tied to ground.
[3]For a step load change of NL-FL or FL-NL, recovery to ± 10mV band.

Table 1-2 Unit Specifications (Sheet 3 of 6)

	ALL	10-50	40-25	60-17	10-100	20-50	40-50	60-35
Drift (typical)[1]	0.025% + 500uV							
Remote Programming								
Prgrm. Constant:								
Res. (ohms/volt)[2]	200±0.5%							
Volt. Gain (volt/-volt)[3]	1							
Remote Sensing	1V/Load Lead							
Overload Protection	Crossover to Current Mode							
Output voltage Over-Shoot	None							
Current Mode:								
Regulation, full line and load (mA)	0.02% + B, where B= :	4	4	4	6	4	4	4
PARD (ripple) 50-60Hz input:								
Max. RMS 10Hz-7MHz (mA) Full compliance (FC)		20	10	3	35	10	10	10

[1] For 8hrs after warmup, @ constant line voltage, load, and ambient temperature.
[2] Can be varied.
[3] Can be varied-signal source can be connected to negative output.

Table 1-2 Unit Specifications (Sheet 4 of 6)

	ALL	10-50	40-25	60-17	10-100	20-50	40-50	60-35
Output Impedance (typ)	Figure 6-5 (Section 6)							
Temperature Coeff. (/°C)(typ)	0.01% + C Where C=	1mA	1mA	1mA	2mA	1mA	1mA	1mA
Drift (For 8hrs after warmup)(typ)	0.03% + D Where D= :	3mA	3mA	3mA	10mA	3mA	3mA	3mA
Remote Programming								
Prgrm. Constant:								
Res. (ohms/amp) Voltage (volts/amp)		20±10% 0.008±10%	40±10% 0.02±10%	50±10% 0.04±10%	10±10% 0.0025 ±10%	20±10% 0.008 ±10%	20±10% 0.008 ±10%	25±10% 0.015± ±10%
Overload Protection	Crossover to Voltage Mode							
Output Current Overshoot	None							
SPECIFICATIONS (MISC.)								
Overvoltage Protection								
Crowbar: Response Time (typ)[1]	To Erated (typ) +6V, 50uSec							

[1] 10uSec response can be achieved by removing C51, although nuisance tripping may result.

Table 1-2 Unit Specifications (Sheet 5 of 6)

	ALL	10-50	40-25	60-17	10-100	20-50	40-50	60-35
Crowbar (cont)								
Temperature Coeff. (typ)	0.05%/°C							
Open Sensing Protection	Yes							
Reverse Voltage Protection	Yes							
Ambient Temperature Range	0°C-71°C							
Derated Per Characteristics	Figure 6-4 (Section 6)							
Series Operation (direct connection or master-slave)	Up to 200 Vdc Output							
Parallel Operation (by current limiting feature or master-slave)	Up to 3 Units							
Cooling	Fan							
Isolation Voltage to Ground:								
Input	1000Vdc							
Output	200Vdc							

Table 1-2 Unit Specifications (Sheet 6 of 6)

MECHANICAL DATA	ALL	10-50	40-25	60-17	10-100	20-50	40-50	60-35
Size (inches):								
Width	19							
Height		5-7/32	5-7/32	5-7/32	6-31/32	6-31/32	6-31/32	6-31/32
Depth		21	21	21	23	21	21	21
Weight (lbs)		81	95	95	132	128	120	120

2 INSTALLATION

2.1 GENERAL

After unpacking, initial inspections and preliminary checkout procedures should be performed to assure that unit is in good working order. Basically, these consist of visually checking for damaged parts and components, and making an electrical check. Procedures are given in this section to check the unit voltage and current modes of operation. If it is determined that the unit is damaged, the carrier should be notified immediately. The carrier claim agent will then prepare a report of damage. The user is required to send this report to the Service Dept., Sorensen Company, 676 Island Pond Road, Manchester, New Hampshire, 03103. Sorensen Company will advise the user as to what action is required to repair or replace the supply.

2.2 INITIAL INSPECTION

Proceed as follows to inspect for damage incurred during shipment, prior to applying ac power:

1. Inspect panel and chassis for dents, paint chips and obvious signs of structural damage.

2. For units with rear-mounted fuseholder, assure that holder contains a properly rated fuse. Fuse ratings for both 115 and 220/230 Vdc inputs appear above holder.

3. Turn front-panel controls from stop-to-stop. Rotation should be smooth.

4. Set POWER switch to ON and then OFF, then test OVERVOLTAGE switch for proper mechanical action.

5. Check for cracked or broken indicator-lamp lens.

6. Inspect for a cracked meter window. If pointer is off zero, reset using adjust screw. (To minimize effects of static electricity causing deflection, touch meter window and chassis with fingers of one hand).

7. Check input cord (where supplied) for physical damage. Tug lightly on cord near chassis to make certain relief grommet grips cord.

8. Inspect terminal boards. On TB2, links should be firmly connected across terminals 1 & 2, 3 & 4, 7 & 8, 9 & 10. Check that sensing leads are properly connected between TB3-1 and TB2-5, and TB3-3 and TB2-6.

9. Remove screws retaining top cover to chassis. Inspect printed circuit board and components for damage.

Unit mounting and installation dimensions are shown in figures 2-1 and 2-2.

2.3 ELECTRICAL INSTALLATION

SRL power supplies are factory-wired to accept 105-125 Vac (standard model), 190-230 Vac (M1 model) or 210-250 Vac (M2 model). Low power units are provided with a factory-wired power cord. This cord terminates externally in a three-prong polarized plug through the line cord, and therefore insertion of the plug into a compatible receptacle will automatically ground the unit. If a grounded input is not available, use an adapter, making sure that the external lead of the adapter is well grounded. For units not equipped with a line cord intact, connect 3-wire input leads to terminals 1, 2 (GRD) and 3 on input terminal board TB1 at the rear of the supply.

CAUTION

If chassis is not grounded, case will be at approximately 55 Vac due to RFI capacitors connected between AC line and chassis. This can produce an unpleasant (although not dangerous) electrical shock.

2.4 ELECTRICAL INSPECTION

The following paragraphs describe the procedure for making an initial electrical inspection. If specification verification is required, refer to section 5, Service and Repair.

2.4.1 Voltage Mode

To check voltage mode operation, proceed as follows:

1. Rotate COARSE CURRENT control and VOLTAGE controls fully counter-clockwise.

2. Rotate FINE CURRENT control fully clockwise.

NOTE

Do not loosen or remove interconnecting links on terminal boards.

3. Insert power cord into a suitable receptacle, and set POWER switch to ON.

4. Slowly rotate the COARSE VOATAGE control clockwise. Minimum range should be from 0 to maximum rated output voltage (table 1-1).

5. Set POWER switch to OFF.

2.4.2 Current Mode

To check current-mode operation, proceed as follows:

1. Rotate COARSE VOLTAGE control and CURRENT controls fully counter-clockwise.

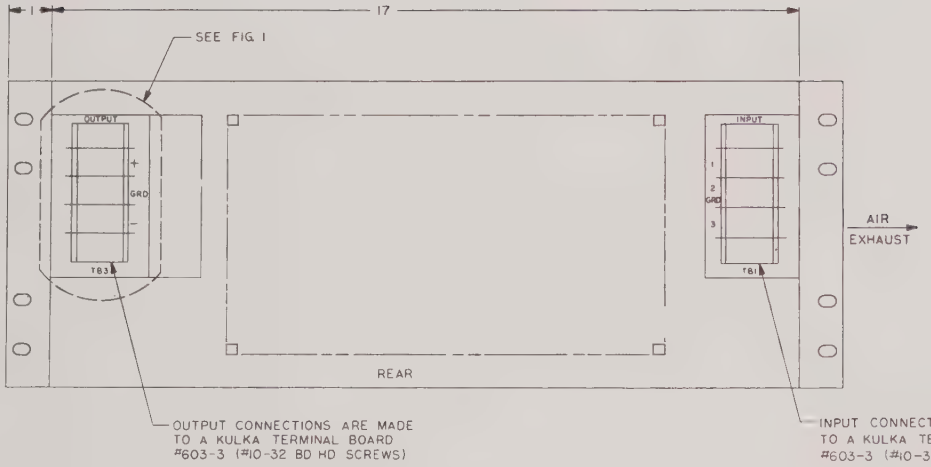
2. Turn FINE VOLTAGE control fully clockwise.

3. Short output terminals, using appropriate size wire. (rear terminals only for units of 25 amperes and above).

4. Set POWER switch to ON.

5. Rotate COARSE CURRENT control slowly clockwise. The control range should be from "0" to the maximum rated output (table 1-1).

6. Set POWER switch to OFF.



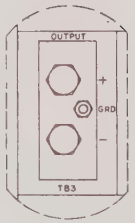
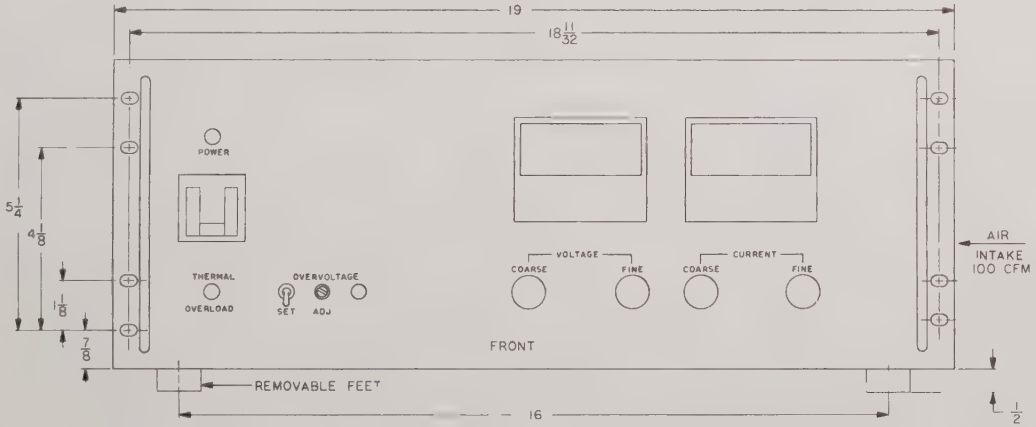
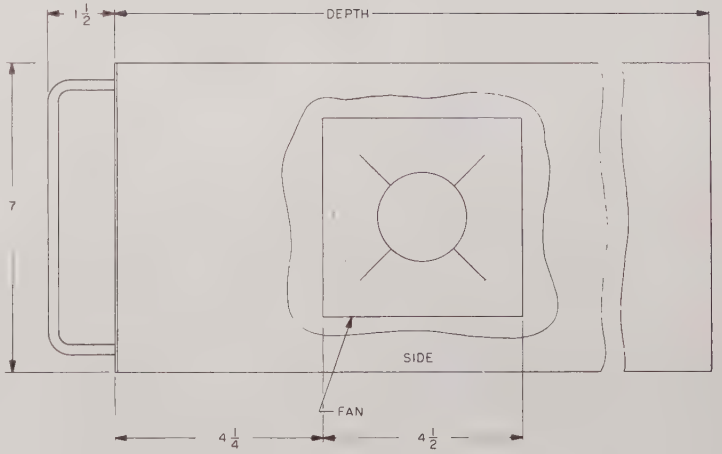


FIG. 1
POST LUG TERMINALS USED ON OUTPUT PORTION OF MODEL NO. SRL10-100 ONLY

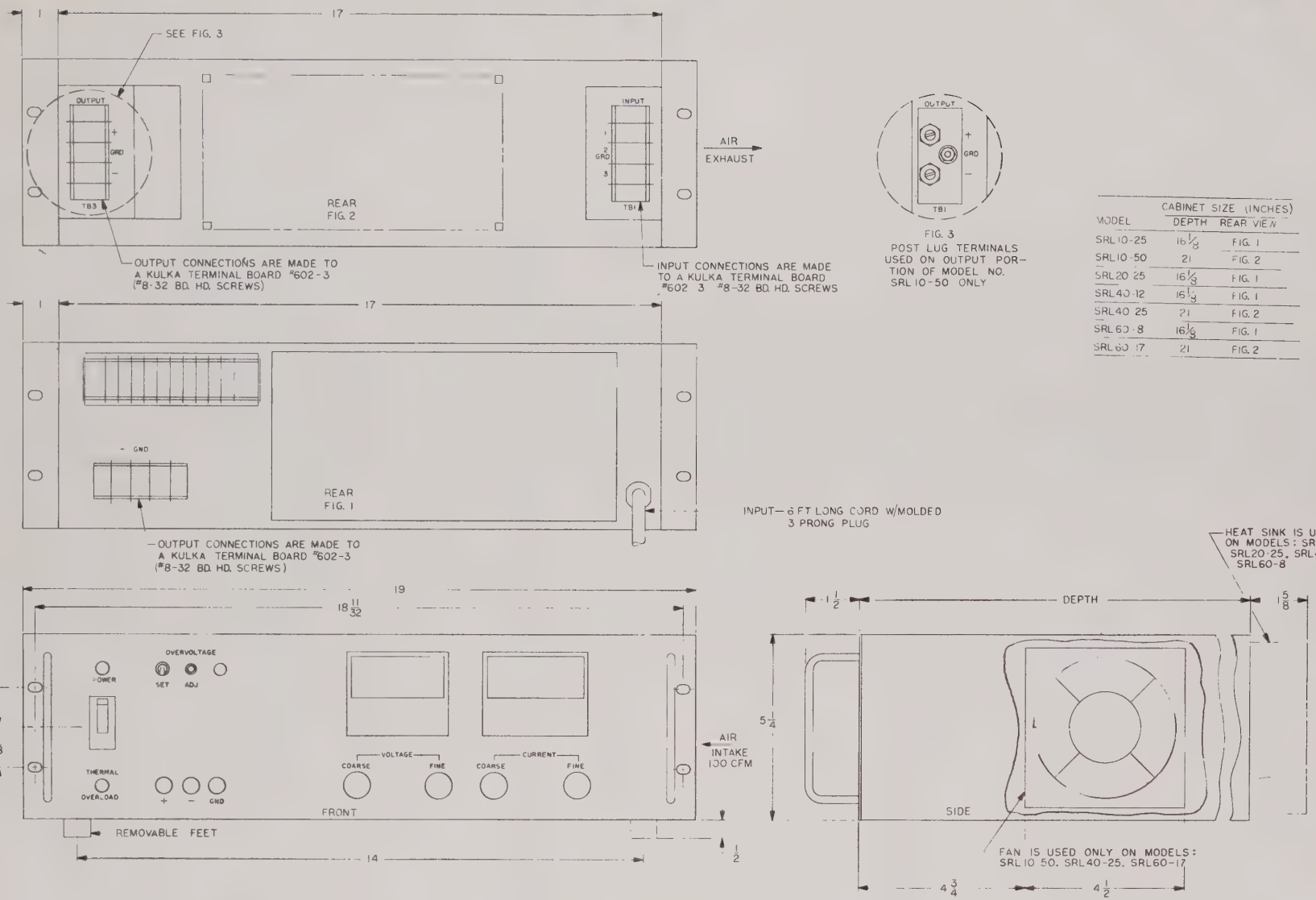




MODEL	DEPTH
SRL10-100	23
SRL20-50	21
SRL40-50	21
SRL60-35	21

DWG NO. E585323 REV. -

FIGURE 2-1
SRL OUTLINE DRAWING
7" PANEL SERIES



MODEL	CABINET SIZE (INCHES) DEPTH	REAR VIEW
SRL10-25	16 1/3	FIG. 1
SRL10-50	21	FIG. 2
SRL20-25	16 1/3	FIG. 1
SRL40-12	16 1/3	FIG. 1
SRL40-25	21	FIG. 2
SRL60-8	16 1/3	FIG. 1
SRL60-17	21	FIG. 2

DWG NO. E585324 REV. -

FIGURE 2-2
SRL OUTLINE DRAWING
5 1/4" PANEL SERIES

3 OPERATION

3.1 GENERAL

In this section, procedures required to convert an SRL unit to any of its various operating configurations are presented, including local and remote sensing, voltage-and current-mode programming, and series and parallel operation. Unit controls and indicators have been illustrated and described in section 1.

3.2 VOLTAGE MODE OPERATION

3.2.1 Local Sensing

All models in the SRL series are shipped ready for use with local sensing, i.e., sensing point is at the output terminals. If variations in load-lead drops are expected to be high relative to unit's specified regulation, remote sensing should be used (paragraph 3.2.2).

To operate unit in local sensing, proceed as follows:

1. To set current-limit value, short the unit output terminals, set POWER switch to ON, and use CURRENT control to adjust current-limit value, indicated on dc amperes meter.

2. Set POWER switch to OFF, remove short.

3. Apply input power, and rotate COARSE and FINE VOLTAGE controls to obtain desired output. Set POWER switch to OFF.

4. Observing polarity, run load leads to either front or rear output terminals, (at rear terminals, link should be fitted between binder screw head and lead); then re-apply input power.

5. Set POWER switch to ON.

3.2.2 Remote Sensing

To adapt unit for remote-sensing operation, follow procedures outlined in preceding paragraphs 1.-4. Before setting POWER switch to ON, remove links between terminals TB3-1 and TB2-5 and TB3-3 and TB2-6. Then connect sensing leads, observing polarity, to TB2-5 &, -6. Use coaxial cable or a twisted pair of wires for sensing leads and make certain that the leads are firmly connected to unit terminals and load. Current in the sensing leads is below 100mA. In remote sensing, standard-programming operation, transient-response characteristics may degenerate slightly.

3.2.3 Remote Programming

In voltage-mode, remote-programming operation, unit output voltage is controlled by external resistance or voltage-signal commands. Both types may be used.

3.2.3.1 Resistance Programming

If the output voltage is to be controlled by resistance programming, calculate the resistance required using the ratio at 200 ± 0.5 ohms/volts, that is for every volt of output desired approximately 200 ohms are required. In selecting a programming resistor, choose one with a low temperature coefficient (±20 ppm/°C) and a wattage ten times that calculated (programming current is normally 5 mA). Note that resitance programming may also be used to improve the unit drift characteristic. For example, if a fixed output is required, a fixed resistor may be selected. This eliminates the variable contact resistance which is inherent in any potentiometer and which contributes to the drift characteristic. If abrupt changes in output voltage are to be made by switching the programming resistance, use a make-before-break switch.

To adapt unit to resistance programming, proceed as follows:

a. Short unit output terminals, set POWER switch to ON. Use the CURRENT control to adjust current-limit value.

b. Set POWER switch to OFF, remove short.

c. Rotate VOLTAGE controls fully counterclockwise.

d. Remove link between terminals TB2-3 and TB2-4, and connect programming resistor. Use twisted or shielded wire for leads.

CAUTION

1. Operating the unit with open programming leads or links may result in either low or high output voltage.

2. With the programming resistor connected across terminals TB2-3 and TB2-4, the VOLTAGE control remains in the circuit. Rotation of this control will alter the programmed voltage. If this is undesirable, connect the resistor across terminals TB2-3 and -6 to effect complete bypass.

3.2.3.2 Changing of Programming Constant

If it becomes desirable to change the programming constant, the value of R21 (programming constant resistor) may be determined as in the following example.

Example: To change the programming coefficient (Pc) from 200 ohms/volt to 1000 ohms/volt, calculate the new value of R21:

$$R21 = V_{ref} \times Pc$$

where Vref is the voltage across C11 (approximately 9 volts). thus;

$$R21 = 9 \text{ volts} \times 1000 \text{ ohms/volt} = 9000 \text{ ohms}$$

The current through R21 is then $\frac{9 \text{ volts}}{9000 \text{ ohms}} = 1$ milliampere.

As noted before, the programming resistor should have a low temperature coefficient, and a wattage rating ten times that of the calculated rating.

To adapt unit to a different resistance programming constant, proceed as follows:

a. Rotate VOLTAGE controls fully counterclockwise.

b. Remove the link between TB2-1 and TB2-2. Install programming constant resistor R21 between TB2-1 and TB2-3 and adjust Vref until the ratio of Vref/R21 is exactly 1 milliampere, or the calculated reference current. This can be done by inserting a resistor in place of R53A (between TB2-3 and -6, with TB2-3 and -4 open) equal to Eout max/1 mA and adjusting the voltage reference potentiometer R9 until Eout is exactly equal to Eout max.

c. Deterioration of the voltage regulation will occur as the programming constant is increased due to the effect of the offset current, and will be proportional to the increase of R21. As an example, if the contribution due to offset current at 200 ohms/volt is 0.002%, at 1000 ohms/volt approximately 0.01% contribution to regulation might be expected.

3.2.3.3 Voltage Signal Programming

To adapt unit for voltage signal programming proceed as follows:

a. Unity Gain (1V/V) (figure 3-1)

1) Remove the input power.

2) Remove the link between TB2-1 and TB2-2.

3) Remove the link between TB2-3 and TB2-4.

4) Connect the signal programming source between TB2-3 and TB2-6. Observe the proper polarity of signal source (negative) on TB2-6.

5) With this modification, the SRL will produce a one volt output for one volt of signal. Do not exceed the rated output voltage of the SRL.

NOTE

The stability and regulation will be a function of the signal source stability.

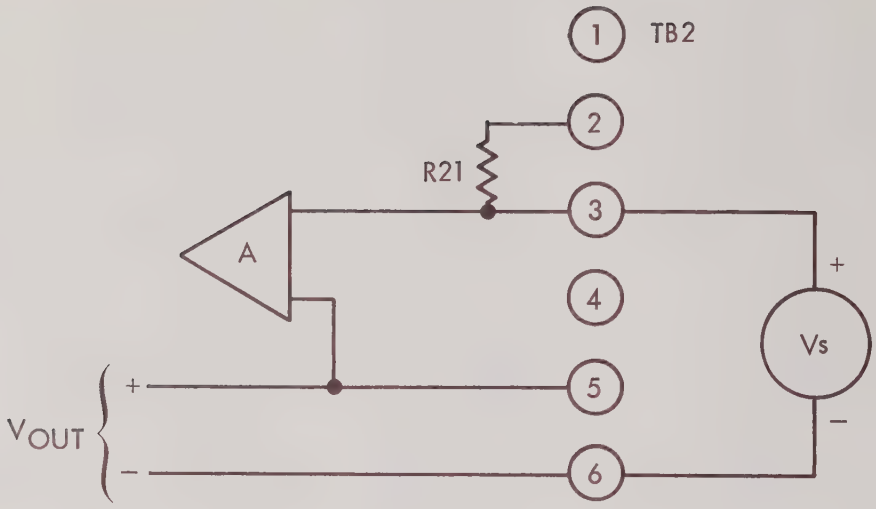


FIGURE 3-1. UNITY GAIN

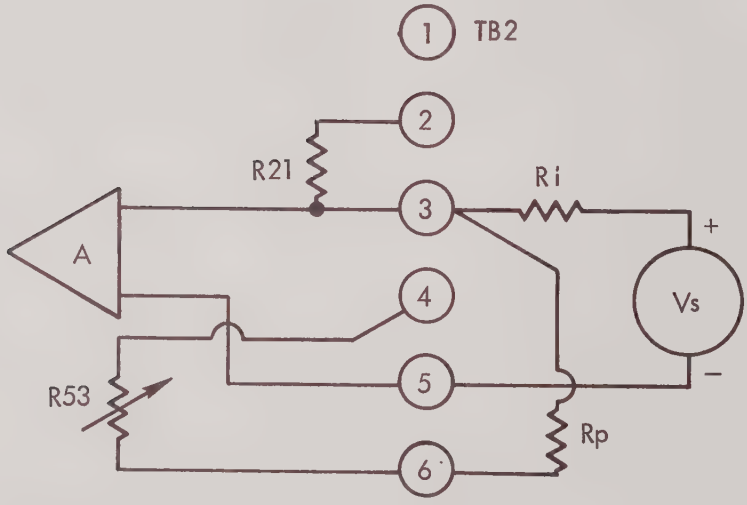


FIGURE 3-2. VARIABLE GAIN

b. Variable Gain (Figure 3-2)

1) Remove the link between TB2-1 and TB2-2.

2) Remove the link between TB2-3 and TB2-4.

3) Place Ri (1.78K suggested) in series with the signal source and connect as shown in figure 3-2 between TB2-3 and TB2-5 observing the proper polarity.

4) As with the previous method of programming, stability will be a function of the signal source stability, its internal impedance, and the stability of Ri and Rp.

In this mode of operation Vo=Vs Rp/Ri assuming the effects of amplifier offset and signal source impedance are negligible. Thus the gain is determined by the ratio Rp/Ri. It is suggested that Ri be made equal to 1.78K ohm or less to minimize the effect of offset voltage. Ri and Rp should be stable resistors (20 ppm/^{o}C or less). Note that the front panel VOLTAGE control R53 may be substitued for Rp if TB2-3 and TB2-4 are linked.

3.3 CURRENT MODE OPERATION

To operate an SRL unit in the current mode, proceed as follows:

1. Rotate all front panel controls fully counterclockwise.
2. Short the output terminals.
3. Rotate FINE VOLTAGE control clockwise, and close POWER switch.
4. Turn COARSE and FINE CURRENT controls clockwise to select the desired output current.
5. Open POWER switch and remove short from output terminals.
6. Set POWER switch to ON and adjust output voltage to desired compliance setting.
7. Open POWER switch, and observing polarity, connect load to terminals TB3-1 and -3. Re-apply input power.

NOTE

If compliance voltage exceeds voltage control setting, crossover to voltage-mode operation occurs automatically.

3.3.1 Remote Programming

In current-mode, remote-programming operation, the regulated output current may be controlled externally by resistance changes or voltage signals.

3.3.1.1 Resistance

For resistance programming, calculate the value of resistor required by using the ohms/ampere coefficient listed in Table 3-1.

TABLE 3-1
PROGRAMMING CONSTANTS
(CURRENT MODE)

SRL MODEL	RESISTIVE OHMS/AMPERE (±10%)	VOLTAGE MILLIVOLTS/AMPERE (±10%)
10-50	20	8
10-100	10	2.5
20-50	20	8
40-25	40	20
40-50	20	8
60-17	60	40
60-35	28	15

Note: Use a resistor with a low temperature coefficient (±20 ppm/^{o}C), and a wattage rating at least ten times calculated value (normal programming current is approximately 1 milliampere).

To adapt unit for current-mode, resistance-programming operation, proceed as follows:

a. Close POWER switch, adjust output voltage to desired compliance setting.

b. Open POWER switch and rotate CURRENT controls fully counterclockwise.

c. Remove link between terminals TB2-7 and -8, and replace with programming resistor.

CAUTION

Operating unit with open programming leads or links will result in high output current with possible crossover to voltage mode. If step changes in output current are to be made by abrupt resistance alterations, use make-before-break switching.

d. Run load to terminals TB3-1 and -3, observing polarity.

e. Set POWER switch to ON. Unit supplies regulated programmed current to the load.

NOTE

Any rotation of the CURRENT control alters the output current.

3.3.1.2 Voltage Signal

To adapt an SRL unit to voltage-signal programming, follow procedures outlined in the previous paragraphs except connect signal-producing device across terminals TB2-7 and -8, instead of the programming resistor. (See Table 3-1) The programming device should be floating (ungrounded), be capable of absorbing the 1mA programming current, and have a low-noise, low-ripple output signal.

3.4 SERIES OPERATION

For applications which require voltages higher than a single SRL model can provide, series operation may be utilized. The maximum rated output of any series connected system is 200 Vdc. System regulation is the sum of the regulations for all units. In SRL models, there is no need to connect reverse-voltage rectifiers across the output terminals. Reverse-voltage protection has been designed into the entire series.

3.4.1 Local Sensing (Figure 3-3 (a))

To connect units in series, local sensing, proceed as follows:

1. Adjust the output voltage of each unit so that their sum is equal to the desired system output. Set POWER switches of each unit to OFF.

2. Disconnect links between terminals TB3-1 and TB2-5, and TB3-3 and TB2-6 of each unit.

3. Reconnect load and sensing leads as shown in figure 3-3, (a).

4. Set POWER switches to ON. The system supplies regulated voltage to the load.

3.4.2 Remote Sensing (Figure 3-3 (b))

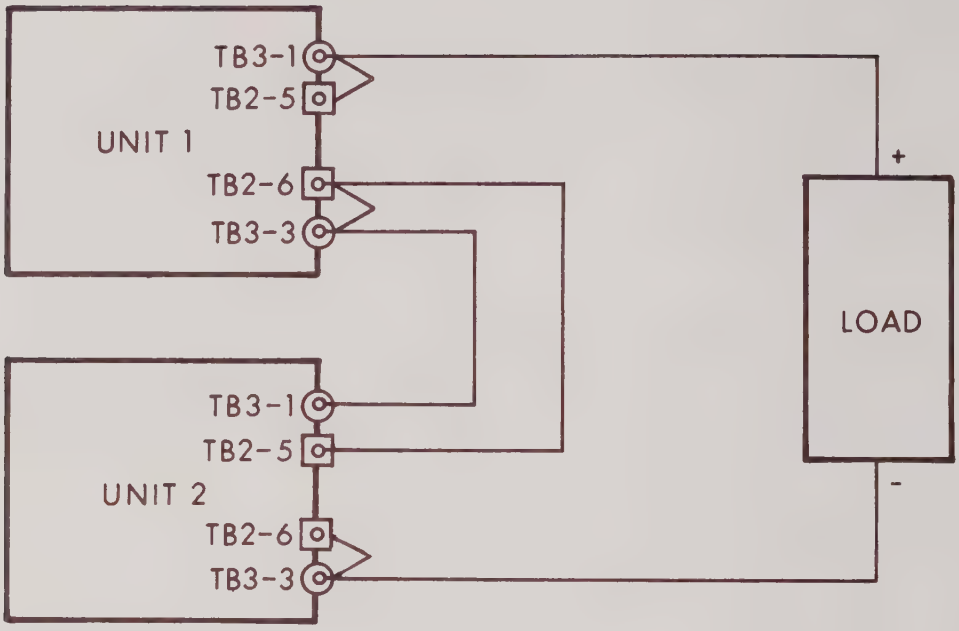
To connect units in series, remote sensing, remove leads from terminals TB2-5 and -6. Observing polarity, connect coaxial cable or a twisted pair of wires from TB2-5 and -6 across load as shown.

NOTE

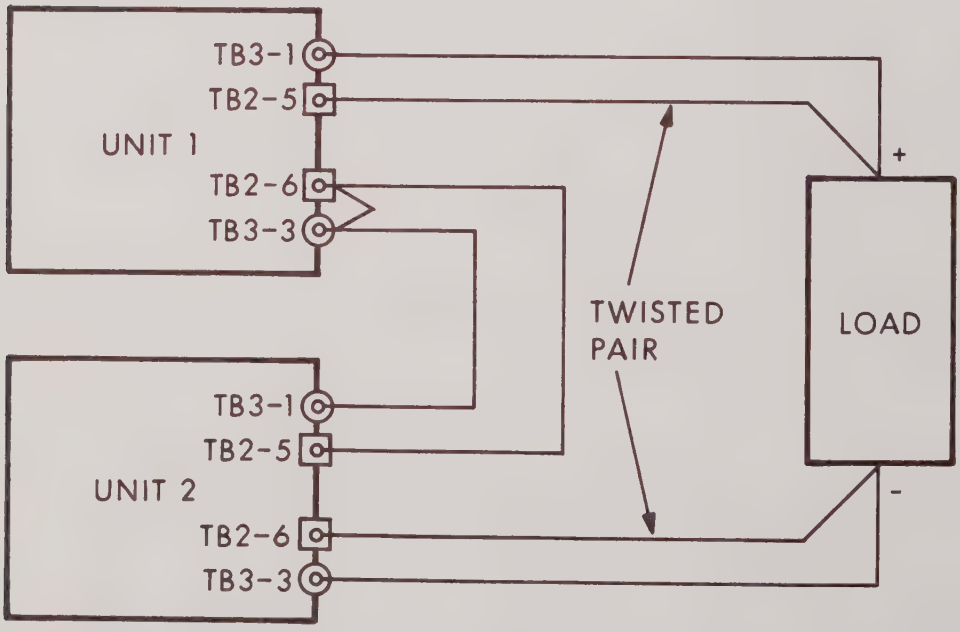
Wherever possible, use twisted or shielded leads. At load and unit terminals, place sensing leads between binder screwhead and load lead.

3.5 PARALLEL OPERATION

Parallel operation may be used to obtain currents greater than any single model can supply. Up to three units may be connected in this manner. The maximum rated output of any parallel-connected system is the sum of the maximum outputs of each unit, derated to 90%.

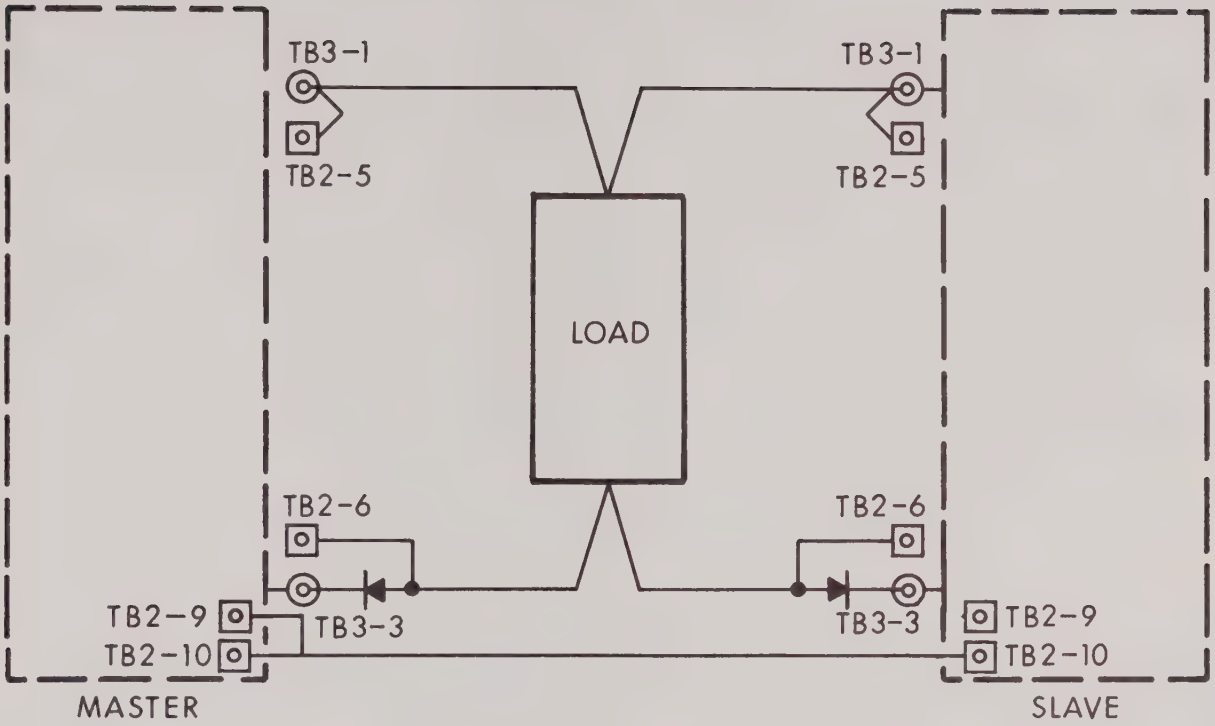


(a) LOCAL SENSING - SERIES OPERATION

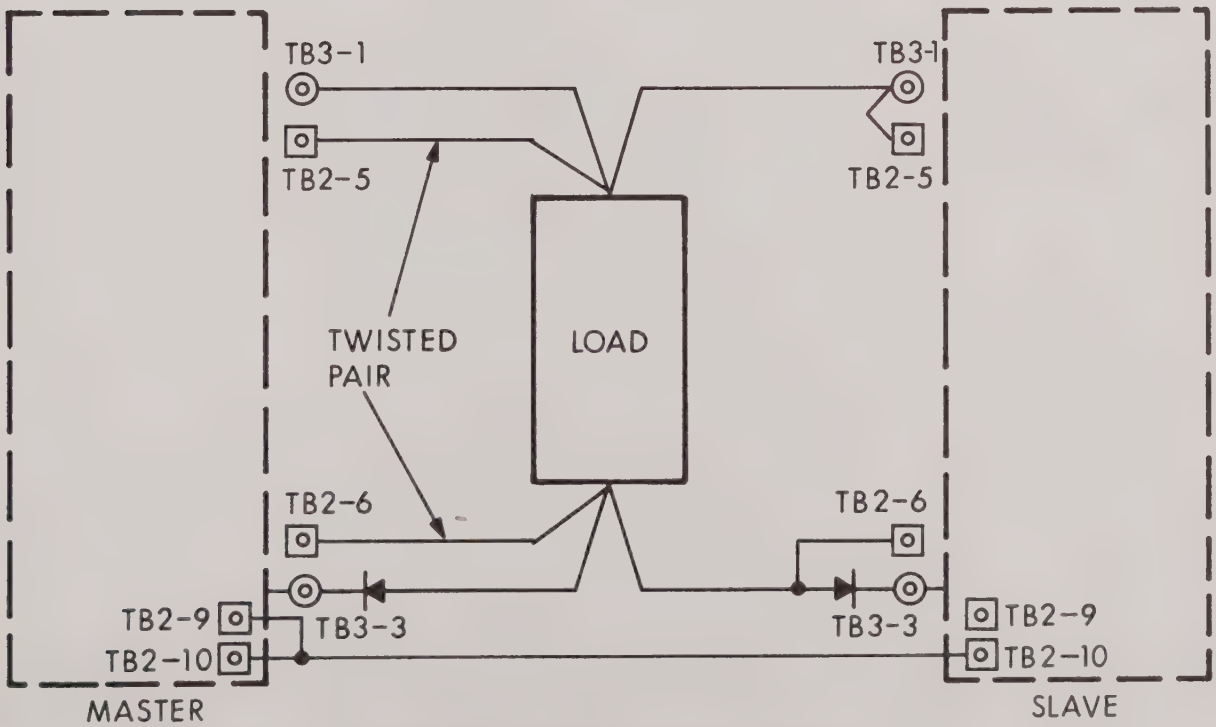


(b) REMOTE SENSING - SERIES OPERATION

FIGURE 3-3 SERIES OPERATION



(a) LOCAL SENSING - PARALLEL OPERATION



(b) REMOTE SENSING - PARALLEL OPERATION

FIGURE 3-4 PARALLEL OPERATION

3.5.1 Local Sensing (Figure 3-4 (a))

To connect two units in parallel, local sensing, (extend this procedure to connect additional units), proceed as follows:

1. Apply nominal input power to "MASTER" unit, and adjust output to desired load voltage. Set POWER switch to OFF.
2. Short master unit output terminals and apply input power. Adjust output current to I_{so}/X, where I_{so} is the total system output current, and X is the number of units in the system. Set POWER switch to OFF.
3. At "SLAVE" unit, remove link from across terminals TB2-9 and -10. Connect a lead between TB3-10 terminals of each unit.
4. Observing polarity, run leads from the load to terminals TB3-1 and TB3-3 on each unit, with (2) diodes connected as shown in (a) of figure 3-4.

NOTE

Assure diode has a current capability at least equal to its associated supply. Connect anode to load in each case.

5. On each unit, open lead between terminals TB2-6 and TB3-3, and connect a lead from TB2-6 to the anode of the diode.

3.5.2 Remote Sensing (figure 3-4 (b))

For remote sensing, remove existing leads from terminals TB2-5 and -6. Observing polarity, connect coaxial cable or twisted pair of wires from TB2-5 and -6 of master unit across load as shown.

4 THEORY OF OPERATION

4.1 GENERAL

This section discusses the basic theory of series pass regulation, describes the block functions of various circuits and then details the operation of each circuit. If used as a supplement to the troubleshooting data provided in section 5, it will aid in the isolation of unit faults. Schematic locations of the reference designations used throughout this section will be found in figure 6-2.

4.2 SCR PRE-REGULATED SERIES PASS PRINCIPLE

The SRL utilizes a combination of SCR pre-regulation and series pass principles to regulate unit output. The series pass function utilizes a variable impedance to absorb the difference between the filtered dc and the desired output voltage in the voltage-mode, and the compliance voltage in the current-mode. The variable impedance is provided by a number of transistor stages connected in parallel, all of which react simultaneously to an output-related control signal. Operation of the transistors, which are called passing stages, is illustrated in Figure 4-1.

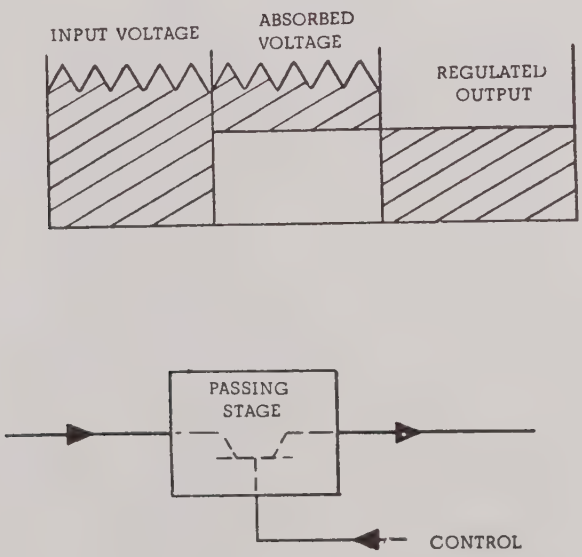


FIGURE 4-1.
SERIES PASS PRINCIPLE

For wide-range power supplies such as in the SRL series, the series pass regulator becomes less practical at higher power output levels. This is due to excessive voltage stored in the passing stage transistor at lower supply output voltages. The method used to restrict the power dissipated in the passing stage is pre-regulation, utilizing a pair of silicon-controlled rectifiers (SCR), whose outputs are controlled to maintain a constant dc voltage across the passing stage. (Paragraph 4.3.6 describes the operation of the pre-regulator circuit).

4.3 SRL POWER SUPPLY THEORY

NOTE

For this system-level discussion refer to the block diagram (Figure 4-2) and system schematic in section 6 (Figure 6-2).

Input power is applied through a phase-controlled SCR circuit consisting of CR 15/16, which function as part of the system pre-regulator circuit, to input transformer T1. The transformer output is then rectified and filtered through full-wave bridge rectifier CR18, sent through the passing stage, consisting of Q13 and associated components, and applied across the output through current and voltage sensing element.

This passing stage is the regulating device absorbing the difference between the pre-regulated dc and the desired or compliance voltages. In voltage-regulating operation, the voltage-mode section Q7, Q8, Q10 senses the output voltage, develops and amplifies error signal, and feeds this signal through a number of drivers to the passing stages. In current-regulating operation, the current-mode section Q3, Q5 monitors the output current through a sensing resistor R41 and regulates the voltage developed across the resistor by applying control signals to the drivers and consequently the passing stage. Unregulated supplies provide reverse-bias and collector supply voltages to the passing stages and forward bias for the current-mode differential amplifiers.

The voltage across the passing stage is sensed by a transistor Q18 through R66 in the pre-regulator circuitry, and compared to a reference voltage developed across R62. Any differential voltage across the base-emitter junction of Q18 is fed back as an error signal to the input SCR through pre-regulator amplifier (Q17), pulse generating circuitry (Q16) and pulse transformer T3.

An overvoltage amplifier (Q19, Q21-24) compares the output voltage to an adjustable reference (set by R85). If this reference is exceeded, the amplifier triggers "crowbar" CR50 which shorts the output of the unit. At the same time, the unit control circuitry is shut off. The unit must be switched off to remove this electronic short circuit.

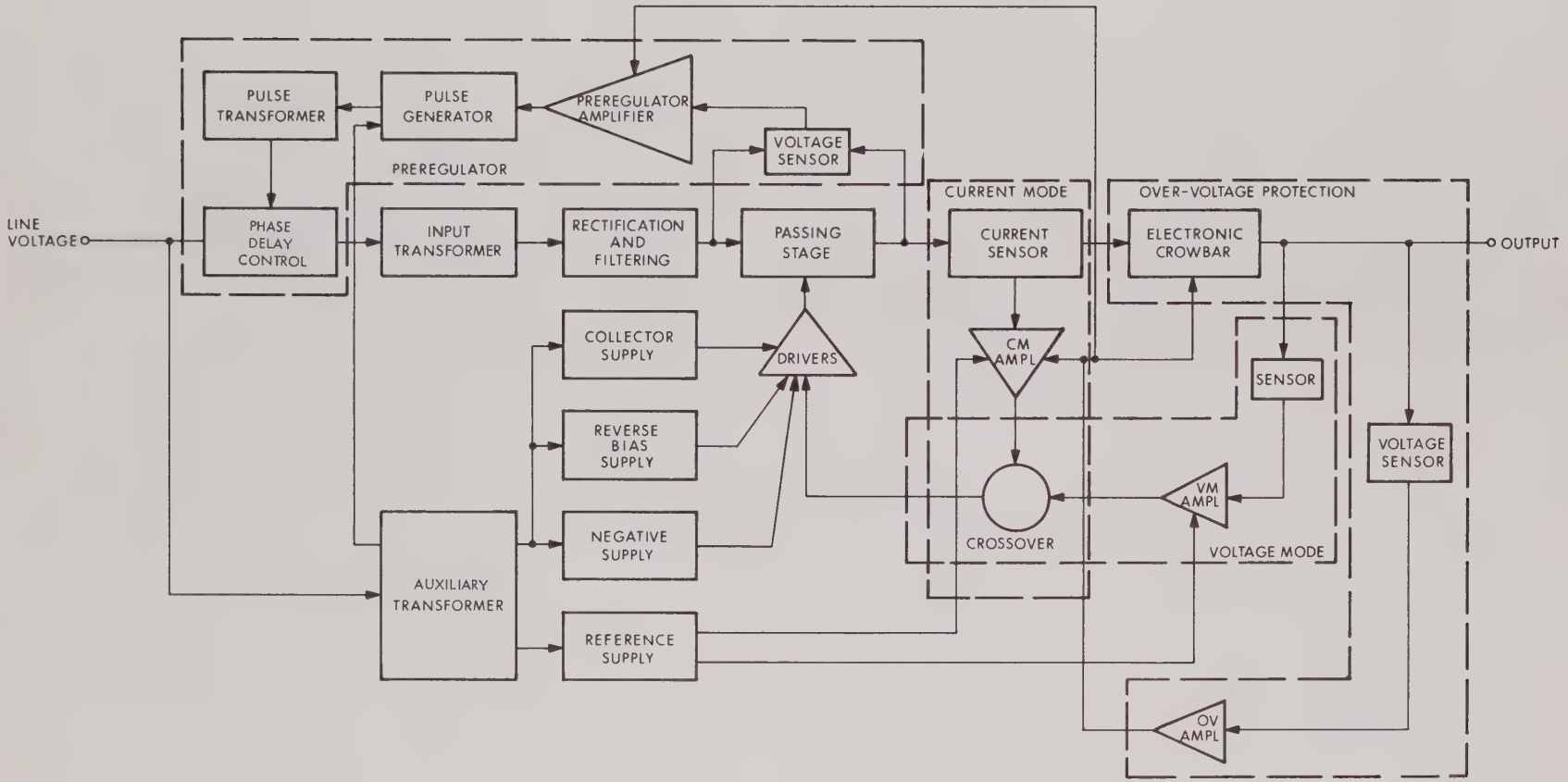


FIGURE 4-2. SRL SYSTEM BLOCK DIAGRAM

4.3.1 Reference Supply

The precisely regulated voltage required for output comparison and error-signal development is provided by a reference supply: (unregulated supply T2, CR1 and CR4), capacitor (C6), an error bridge (R5, R9 and CR5), two double-differential amplifiers (Q2) and a low-power passing stage (Q1). Resistor (R2) is a starting resistor, i.e., at turn-on it shunts current across the passing stage to allow the reference supply to start functioning.

In general, the supply operates as follows: the precise reference voltage developed by zener diode (CR5) is compared with a portion of the output voltage developed across R9. Error signal which develops is amplified first by differential amplifier (Q2-1/2-2) and then by amplifier (Q2-3/2-4). The amplified signal is then applied to the base of Q1, where it alters stage impedance and therefore the absorbed voltage.

As a specific example of circuit operation, assume that, as a result of an input line change, supply output voltage starts to increase. The voltage across R9 will then increase, and the base of Q2-2 will become more positive with respect to the base of Q2-1. Q2-2 will then conduct more current and Q2-1 less. (Note that the sum of the currents through Q2-1 and Q2-2 is held constant by the zener voltage across R8). With an increase in current, the voltage developed across R7 increases, while that across R6 decreases. The base of Q2-4 will therefore become more negative with respect to the base of Q2-3. As a result, Q2-4 will conduct less current, and the drive on Q1 will diminish. Q1 will increase its absorbed voltage, thereby regulating the output to a precise 8.9 volts.

4.3.2 Voltage-Mode Section

The voltage-mode section consists basically of two double-differential amplifiers (Q10-1, 10-2, and Q7, Q8), a constant-current generator (Q10-3) and sensing string (R21, R53A and B). The section functions to sense unit output voltage, to detect differences between the desired and the actual output voltages, and to convert and amplify these differences into error signals used to control passing-stage (Q13) impedance.

To clarify circuit operation, a specific example is given. Suppose that as a result of a load change the output voltage begins to increase. The increase is sensed across R53A and B, and Q16 base becomes more negative with respect to the base of Q10-2, which is connected to the positive sense terminal TB2-5. Current through Q10-1 decreases while that through Q10-2 increases. (The sum of the Q10 operating currents is fixed by constant-current generator Q10-3, R37, CR12 and 13). The decreasing current through R23 lowers its voltage while that across R24 increases. As a result, the base of Q7 becomes less negative with respect to the base of Q8, and the Q7's operating current decreases. This operating current is then the signal current to the drivers and passing stages, and any changes in it are reflected in changes in passing-stage impedance and consequently output voltage. A constant current source consisting of Q3-3 and R44 keeps Q7 operating in the high-gain region. A decrease in signal current,

resulting from an increase in output voltage, increases passing-stage impedance to reduce the output to the desired voltage.

Transistor Q9, diode CR10 and resistor R24 form the down-programming-time circuit. Under normal operating conditions, Q9 is nonconducting due to insufficient base-emitter voltage. However, when a programming-resistance or voltage-signal change is made to lower the output voltage, Q9 goes rapidly into conduction and almost instantaneously shunts the previously mentioned signal current into the sensing string. As a result, no signal is impressed on the drivers and the passing-stage impedance increases, absorbing more voltage.

As the bases of Q16 and Q17 regain their equilibrium, Q9 reverts to its nonconducting state, and normal regulation at the programmed voltage takes place.

4.3.3 Power-Limiting Circuit

In normal operation the passing stage voltage is kept constant by the preregulator. When the output is shorted, the voltage, and thus the power dissipated by the passing stage will exceed the maximum limits until input capacitor C23 reaches it final value. Therefore a power limiting, or protective circuit consisting of Q15, R49 and associated components has been included to limit the current through the passing stage.

Transistor Q15 senses the voltage across R49, as the voltage across the passing stage. In normal operation, the base/emitter junction is reverse-biased, and no collector current flows. As the passing stage voltage increases, the base of Q15 becomes more positive with respect to the emitter and turns Q15 on. The collector current then absorbs the current-mode reference current from Q6. This lowers the maximum current capable of being delivered by the passing stage, thus limiting the power dissipation.

4.3.4 Current-Mode Section

The current-mode section serves two functions. In constant-voltage operation, it protects the load from excessive currents by limiting action, and in constant-current operation, it regulates the output current to the desired value. Main components include differential amplifers (Q3-1 and -2, and Q5-1 and -2), constant-current generator (Q6), sensing resistor R41, switch (Q3-3) and potentiometers (R18A/B). (R15) is a calibration resistor used to adjust amplifier (Q5-1 and -2) zero-set point.

Basically, the current section functions as follows: the voltage across sensing resistor (R41), developed by the load current, is compared to a fixed reference. This reference is derived from 8.9-V regulated supply and the constant-current generator (CR9, R17 and Q6) Any error signal which developes is amplified first by Q5-1 and -2, and by Q3-1 and -2, and then by Q3-1 and -2. A constant current source composed of Q4, R12, CR6 and CR7 is used to increase the collector impedance of Q3-2 and consequently the gain of the stage. The amplified signal is then applied to the base of switch Q3-3, which then functions as a variable impedance

to control the signal from the voltage-mode section to the driver and passing stages. It should be noted that the signal from the voltage-mode section is at full strength and that, in voltage-mode operation, Q3-3 is saturated.

As a specific example of current-mode-section operation, suppose that the load current begins to drop below the setting of the output current adjust (R18A and B). The voltage across R41 decreases, and the base of Q5-1 becomes negative with respect to the base of Q5-2. The operating current through Q5-1 increases and more voltage builds up across R31. As a result, the base of Q3-1 becomes more positive with respect to the base of Q3-2. The operating current through Q3-1 will then increase while that through Q3-2 decreases. As a result, the voltage developed across R10 drops, and the drive on Q3-3 increases. Q3-3's impedance will decrease, and the signal current to the drivers and passing stages will be greater. Consequently, passing stage impedance decreases, and output current increases to the regulator setting.

4.3.5 Drivers and Passing Stages

Basic components in the drivers and passing stages include transistors Q11/14, Q12, and Q13. Driver Q11/14 amplifies the signal produced by either the voltage-or current-mode sections, and applies to it the base of Q12 for further amplification. The amplified signals are then applied to the passing stage bases where they act to alter stage impedance, thereby controlling the output voltage or current. R40 assures equal current sharing amoung the passing stage.

4.3.6 Pre-Regulator

The pre-regulator section consists primarily of reference transistor Q20, amplifiers Q17, and Q18, pulse generator Q16 and transformer T3.
The function of the pre-regulator is to generate and control the firing pulses for the input SCR, thus controlling the voltage appearing across the passing stage network.

The pulse-forming section is composed of unijunction transistor Q16, capacitor C39, and zener diode CR38. This circuit produces pulses at the secondary of T3 which are synchronized to the zero crossing of the input sinewave voltage of T2 (see figure 6-7). CR38 maintains a constant voltage to operate the uni-junction transistor Q16. When the input sinewave voltage goes to zero at the end of each half-cycle, the zener voltage collapses toward zero. Uni-junction Q16 fires and resets the voltage across C39, which then recharges through R60 to a "pedestal" voltage established by the voltage at the collector of amplifier Q17.

Q16 will fire when its firing potential, (pre-determined at approximately 50% of the voltage across CR38) is reached by C39. A firing pulse is then produced and transmitted to the SCR through T3. The time taken for C39 to charge to the firing potential is controlled by the level of the pedestal voltage, which is a function of the collector current of Q17. The base of Q17 is driven by the error signal of pre-regulator amplifier Q18. Figure 6-7 depicts typical pulse-forming network waveforms as related to the rectified input waveform.

The pre-regulator amplifier section senses the voltage across the passing stage, and produces an error signal proportional to any increase or decrease in the passing stage voltage. This signal is such that if the voltage increases, the current through Q17 increases, lowering the pedestal voltage, causing the firing angle of the primary SCR to be delayed, and in turn maintaining the passing stage voltage relatively constant.

4.3.7 Overvoltage Protection

This circuit compares the output voltage with a preset reference voltage and activates electronic "crowbar" CR50 when this limit is exceeded. S2 on the front panel (OVERVOLTAGE SET) provides for monitoring the reference tripping voltage level.

The reference voltage is established by OVERVOLTAGE ADJ potentiometer R85 on the front panel, and appears on the base of Q23, which is half of the Q22/Q23 differential comparator. The power supply output voltage is applied to the base of Q22, whose output is applied to CR50 through SCR diode CR45. When CR45 fires, due to an overvoltage condition, it triggers the crowbar which clamps the output voltage at zero, activates the OVERVOLTAGE indicator DS2 on the front panel and cuts off the input of the pre-regulator through Q19 and CR44, calling for maximum phase delay, thus reducing the dc input voltage. Transistors Q24/Q25 act as a "turn-on" circuit, which prevents the overvoltage circuitry from triggering during unit turn-on/turn-off.

4.3.8 Reverse-Bias Section

The reverse-bias section functions (1) during "load-off" transients to improve response time by rapidly cutting off the passing stages and (2) to absorb "thermal-effect" current generated by high-junction temperature. The section is comprised of an unregulated supply and a number of biasing resistors.

A secondary of transformer T2, rectifiers CR22/CR23 and capacitor C2 form a supply which feeds reverse bias through R45-48 to transistors Q11, Q12, and Q13.

4.3.9 Stabilization

A tendency toward instability under certain operating conditions is inherent in the operation of any high-gain feedback amplifier. To preclude unstable operation, SRL power supplies have been equipped with a number of stabilization networks and capacitors. In the voltage-mode section, these include networks C30-R54, C15-R20 and capacitors C13, C16 and C43. The current-mode section includes network C12-R16, and capacitor C14. Network C9-R3 and capacitor C3 are used in the reference supply, and capacitors C24/C25 stabilize drivers Q12 and Q11/Q14.

4.3.10 Power Section

In the power section, ac line voltage is applied to the primary of T1 through input filter L1, and SCR's CR15/CR16. The output of the secondary is rectified by full wave bridge rectifier CR18, and filtered by capacitor C23 before being delivered to the passing stage input.

4.3.11 Thermal Overload Section

The thermal overload section consisting of thermostat S3, resistor R95, diode CR57 and indicator DS3, functions when unit temperature exceeds a predetermined limit. When this limit is reached, thermostat S3 closes, and the voltage across R74 is sufficient to cut off the pre-regulators, thus blocking the primary DCR's and removing the dc input to the unit.

4.3.12 Collector Supply

In order to limit the voltage across the passing stage, a separate bias supply provides collector bias voltages to the passing stage driver transistors Q11, Q12 and Q14. This supply consists of secondary T2-15, -16 and -17, diodes CR27/ CR28, and capacitor C26.

5 SERVICE AND REPAIR

5.1 GENERAL

This section provides periodic-servicing information, troubleshooting data, calibration procedures and performance testing procedures. The trouble-shooting data should be used in conjunction with both the schematic diagram (Figure 6-2), which gives voltage-check points, and Section 4, which outlines the principles of operation. Figure 6-1 physically locates the parts appearing on the schematic. Any questions pertaining to repair should be directed to the nearest service representative, or to the Service Dept., Sorensen Company, 676 Island Pond Road, Manchester, New Hampshire, 03103. Include the model and serial numbers in any correspondence. Should it be necessary to return a unit to the factory for repair, authorization from the Service Department must be obtained first. Sorensen Company will not assume responsibility for units returned without prior authorization.

5.2 PERIODIC SERVICING

Units in the SRL series do not require periodic servicing. However, it is recommended that whenever a unit is removed from the line it be cleaned. Naptha, or an equivalent solvent should be used on painted surfaces. The front panel may be washed with a weak solution of soap and warm water. To remove dust from in and around parts, compressed air at a pressure of approximately 5 PSI should be used.

5.3 TROUBLESHOOTING

Table 5-2 provides a list of malfunction symptoms along with a tabulation of the possible cause or causes for each symptom. Note that the failure of one component may result in a "chain reaction" effect. For example, if one of the passing stages (Q13) opens, the remaining Q13 (where provided) may become overloaded and subsequently fail. In a like manner, if a diode in one of the full-wave rectifiers fails, its complementary rectifier and the main transformer may be damaged.

The data listed in Table 5-2 is based on prototype reliability studies, not on actual solutions to field problems, and therefore may be imcomplete. Where the probable cause for a symptom lists a transistor short, it is either a base-collector, emitter-collector or base-emitter-collector short. Base-emitter shorts may give an entirely different set of symptoms. It is therefore recommended that before a particular section is checked for failures, each transistor within the section be tested for base-emitter shorts. (Typical base-emitter voltage is approximately 0.6 volt.)

5.4 CALIBRATION

Following repair, the unit should be re-calibrated to insure that replacement components have not appreciably altered performance characteristics. When calibrating, follow the sequence outlined in the following paragraphs.

NOTE

If under full load, at high/low line inputs, the dc passing stage voltage (from C23 (+) to positive output terminal) is within ±10% of item A, Table 5-1, further calibration of the unit should not be necessary.

5.4.1 Pre-Test Inspection

Check that links are firmly in place across barriers on terminal board and leads between sensing and output terminals.

5.4.2 Preliminary Adjustments

1. Pre-Regulator

a. On the printed circuit board, turn potentiometers R9 (reference adjust), R15 (current mode zero adjust) and R63 (passing stage voltage set) to midpoint in rotation range; turn R78 (Pre-regulator firing angle control) fully counterclockwise.

b. On the front panel, turn VOLTAGE mode COARSE control (R53A), FINE control (R53B), CURRENT mode COARSE control (R18A), FINE control (R18B) and OVERVOLTAGE SET (R85) fully clockwise.

c. Connect a voltmeter across C11 (reference supply output).

d. With nominal* input voltage applied at 60 Hz to the input and with no load applied, set POWER switch to ON. Pilot light should glow.

e. Adjust R9 to obtain approximately 9V across C11.

f. Set POWER switch to OFF, disconnect voltmeter from C11.

g. Connect a voltmeter from positive terminal of C23 to positive output terminal, (hereafter referred to as passing stage voltage). Rotate R78 clockwise. Connect an oscilloscope across terminals 4 and 5 of transformer T3.

h. Set POWER switch to ON. Set input voltage to 125 or 230 Vac (as applicable). Adjust R63 to obtain a passing-stage voltage approximately equal to that specified in item A of Table 5-1. Adjust output voltage to rated voltage (Item B, Table 5-1) and apply rated load current (Item C, Table 5-1).

Decrease R78 so that the output voltage decreases to approximately 50% of the rated output. Observe waveform on the oscilloscope. It should be similar to that in Figure 5-1. Gradually decrease the input line voltage with variable control while also increasing the output voltage by means of R78. Continue this procedure until time "t" reaches a minimum of 0.5 ± 0.2 milliseconds. The output voltage should now be equal to the rated output. Vary the input line voltage and check that "t" is at a minimum null. If "t" is not at a minimum null, readjust R78 at the line voltage where "t" is at a minimum null. This line voltage should be no higher than approximately 105Vac (190 Vac for nominal 210 Vac input models). Check the waveform across T3 terminals 7 and 8. It should be similar to that across terminals 4 and 5.

*Nominal: 115, 210 or 230 Vac as applicable.

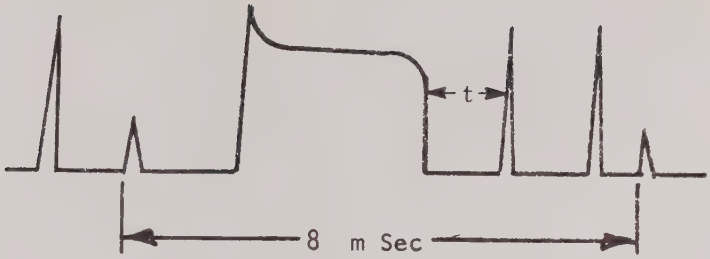


FIGURE 5-1 - T3 SCOPE DISPLAY

Set line voltage to 125 Vac (or 230 Vac for the 190-230 input models) and check passing stage voltage Item A in Table 5-1. Set POWER switch to OFF. Apply locking compound to R63 and R78. Remove oscilloscope from transformer T3 and voltmeter from C23 (+) to positive output.

2. Voltage-Mode Calibration

   a. At the rear terminal board (mounted on the printed circuit board) remove link between terminals 3 and 4 and connect a precision resistance set exactly to that value specified under Item D in Table 5-1. Assure that the leads are firmly connected both at terminal board and at box.

   b. Connect a precision voltmeter (J. Fluke or equivalent) across rear output terminals.

   c. With nominal input voltage at 60 Hz applied to input, set POWER switch to ON.

   d. Adjust R9 to obtain output voltage specified under Item B, Table 5-1. Apply locking compound to R9.

Table 5-1, Difference Data

Item	10-50	40-25	60-17	10-100	20-50	40-50	60-35
A (V dc)	5.4±0.1	9.9±0.1	13.7±0.1	5.4±0.1	7.0±0.1	8.5±0.1	13.4±0.1
B (V dc)	10±0.035	40±0.14	60±0.21	10±0.035	20±0.07	40±0.14	60±0.21
C (A dc)	50	25	17	100	50	50	35
D (ohms)	2000	8000	12,000	2000	4000	8000	12,000
E (mA)	±50	±25	±15	±100	±50	±50	±20

3. Current-Mode Calibration

   a. Rotate COARSE and FINE CURRENT controls fully counter-clockwise. Set POWER switch to OFF. Connect appropriate ammeter in series with the load.

   b. Set POWER switch to ON, and adjust R15 to obtain current between zero and that specified under Item E, Table 5-1. Apply locking compound to R15. Set POWER switch to OFF. Remove ammeter.

5.5 PERFORMANCE TEST

Sensitive instruments such as the SRL series require rigorous testing methods if a true evaluation of performance is to be made. Wherever possible, twisted leads should be used with test equipment to reduce stray pickup. At the power supply terminal board, these leads must be firmly screwed to the terminals. Alligator clips and similar types of connectors are not suitable. Note that the output specifications are applicable at rear terminals only. (Front panel binding posts may introduce errors which, although small, are sufficient to adversely influence measurements.) In addition, grounding techniques in which more than one device in the test system is grounded (excluding ac inputs) may introduce extraneous ripple through ground loops. Although unrelated to supply output, this ripple will be displayed on the test oscilloscope.

5.5.1 Voltage-Mode Regulation

To check voltage-mode regulation, connect test system as shown in Figure 5-2. For regulation testing, the oscilloscope and RMS voltmeter are not required. Use a variable autotransformer for ac input, connect an ac voltmeter across tranformer output terminals and proceed as follows:

1. At no load, adjust output to maximum rated voltage.

2. Adjust differential voltmeter internal voltage to obtain a null indication.

3. With proper (nominal) input applied, load the unit until dc ammeter indicates rated output current (at 55°C). Record deviation from null position.

4. Decrease the input by 10%, and readjust voltmeter internal voltage to regain the null position. With full load on unit, reset the input to 10% above nominal. Note the deviation from null. This shall be equal to, or less than the specification listed in Table 1-2.

5.5.2 Voltage-Mode PARD*

To check a periodic and random deviations in the voltage mode, connect a true RMS voltmeter and oscilloscope across unit sense terminals as shown in

* Deviation in output voltage from its average value.

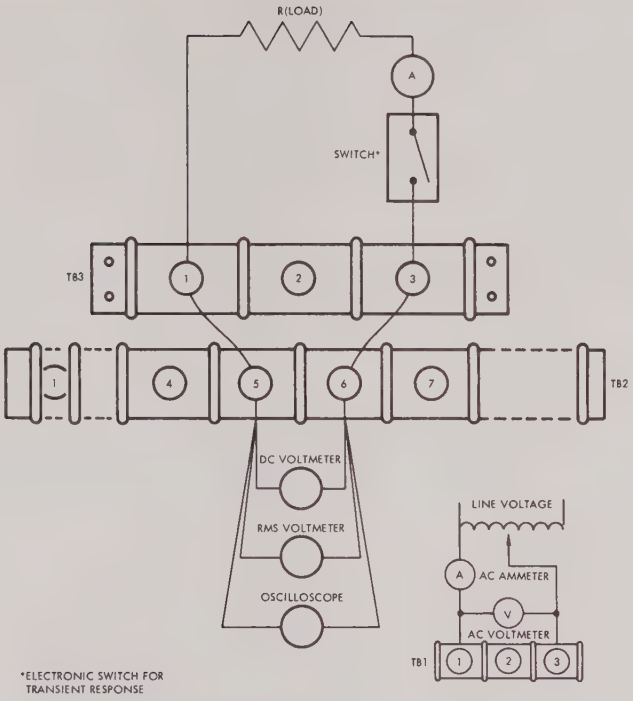


FIGURE 5-2
VOLTAGE MODE
PERFORMANCE TEST SETUP

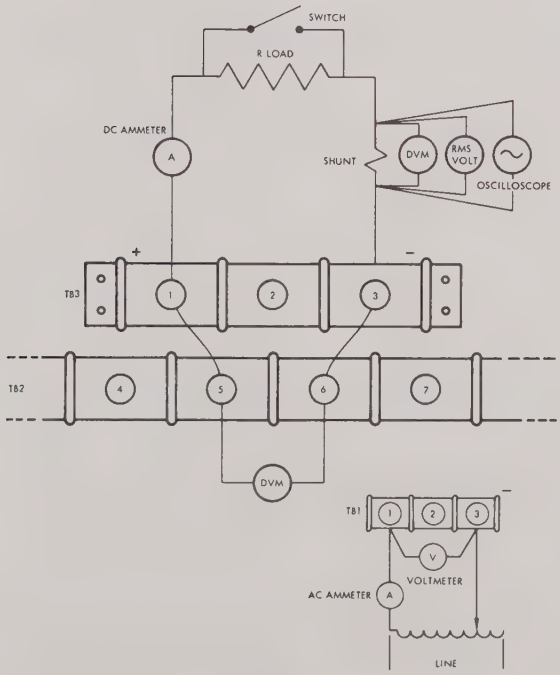


FIGURE 5-3
CURRENT MODE
PERFORMANCE TEST SETUP

Figure 5-2. RMS voltmeter should have a 10Hz-7MHz bandwidth and bandwidth of oscilloscope should be 0-25 MHz. Proceed as follows:

1. Apply nominal input voltage.

2. At no load, adjust unit output voltage to maximum rated.

3. Apply load until dc ammeter indicates rated output current at 55°C.

4. Observe oscilloscope and voltmeter. Maximum RMS and peak voltages should not exceed the specifications as noted in Table 1-2.

5.5.3 Current-Mode Regulation

This test consists of measuring the voltage-drop deviation resulting from a full-line swing and a full-load change across a shunt resistor. Set up test equipment as shown in Figure 5-3. If possible, select a precision (± 1%) shunt which will provide a voltage drop of approximately 0.5 volt at unit maximum rated current. Also, to reduce temperature-coefficient effects, the shunt selected should be capable of dissipating 10 times the maximum power output attainable. The load must be able to absorb the full compliance voltage. For regulation testing, the true RMS voltmeter and oscilloscope are not required. Proceed as follows:

1. At no load, rotate VOLTAGE controls fully clockwise. Note the output indicated on the digital voltmeter.

2. Apply load until output drops to exactly the maximum rated compliance voltage.

3. Set internal voltage of differential voltmeter to obtain a null indication.

4. Close load-shorting switch and record deviation.

5. Open switch and adjust input voltage to 10% below nominal. If necessary, reset voltmeter to null position and then vary the input to 10% above nominal. Note any deviation.

The sum of the deviations obtained should be no greater than that specified in table 1-2.

5.5.4 Current-Mode PARD

To check current-mode periodic and random deviations, connect a true RMS voltmeter and an oscilloscope across shunt as shown in Figure 5-3. The differential voltmeter is not required. Load resistor should be noninductive. Proceed as follows:

1. Set input voltage to 10% above nominal.

2. Apply sufficient load to obtain maximum compliance-voltage indication on digital voltmeter.

3. Observe RMS voltmeter and oscilloscope. Maximum allowable RMS current should not be greater than that specified in Table 1-2.

5.5.5 Drift

The drift in both voltage and current modes are measured using a strip-chart recorder at constant load, line and ambient temperature. Allow one-half hour for voltage-mode warmup and a full hour for current-mode warmup. Drift specifications are listed in Table 1-2.

TABLE 5-2 SRL TROUBLESHOOTING CHART

SYMPTOM	PROBABLE CAUSE	REMEDY
I No Output, Pilot light does not glow	Internal Fuse (F2)	Replace F2
II Low or No Output-Voltage Mode	A. Overvoltage circuitry	1. Check that DS2 (OVERVOLTAGE) on front panel is not illuminated 2. Set S2 to overvoltage set position and read level on meter. Adjust R85 (OV ADJ on front panel) to its maximum level. Switch unit off, and on again after a few moments. If problem does not disappear, determine if output current adjust (R18) functions properly. If so, check for CR50 short. If R18 does not function, check for CR45 short, or defective Q22-Q25.
	B. No pre-regulator output (no voltage across C23).	1. Check for presence of firing pulses at T3-4 and -5, or T3-7 and -8 (See Figure 6-7). If pulse is present, SCR CR15, or 16 defective. 2. If no pulse at T3, check signal across CR38 (Figure 6-7). If proper signal exists, check for defective transistors Q16 or Q17. 3. If CR38 signal is not correct check CR38, CR35 or CR36.
	C. 4.7-volt supply	Check for 4.7 volts across CR29. If incorrect, check CR29 or R28.
	D. 9-volt supply	Check for proper voltage across C11. If incorrect adjust using R9. If no effect, defective Q1 or IC Q2.
	E. Current Mode section	Short Q3-3. If output voltage exists, check for defective Q5, Q3-1, Q3-2 or Q4.
	F. Voltage Mode section	Short Q3-3. If no output voltage, check bias across CR11. If forward-biased check Q7, Q8 and check for shorted Q3-4. If reverse-biased, replace Q10 and check for shorted Q3-4.

TABLE 5-2 SRL TROUBLESHOOTING CHART

SYMPTOM	PROBABLE CAUSE	REMEDY
II Low or No Output, Voltage Mode (continued)	G. Drivers or Passing Stage	Check for open Q11-Q14.
III High Output, Voltage Mode	A. Reference supply	Output should be ripple-free at 8.9 Vdc. If adjustment with R9 is to no avail, check for shorted Q1, or defective Q2.
	B. Drivers or Passing Stage	Short TB2-9 to TB2-5. If no change, check for shorted Q11-Q14. If problem disappears, check for open Q3-4, Q8, or defective Q10 or shorted Q7. Check for presence of 4.7 volts across CR29.
IV Low Output, Current Mode	Current Mode Section	1. Check for 2.7 volts across CR9. Drop across R17 should be 0.6 volt less. If not, defective Q6. 2. Place short across Q3-3. If no change, check for open Q7. 3. Check for Q15 leakage or shorted or defective associated components. 4. Check for defective Q5 or Q3.
V High Output, Current Mode	Current Mode Section	1. Same as IV-1. above. 2. Check for shorted Q3-3 or defective Q5 or Q3.
VI Repeated shutsown of unit due to thermostat operation.	Excessive voltage across C23, due to: A. Pre-regulator B. Passing stage C. Fan inoperative	 CR15/CR16 SCR Shorted components. Check Q11-Q14. Check fan motor or restriction of fan blade.

6 DRAWINGS AND PARTS LISTS

6.1 GENERAL

This section contains all the reference drawings referred to throughout the text. Included are the system schematics, typical printed circuit board showing component layout, typical chassis assembly photographs with major components called out, and typical impedance and crossover characteristic curves.

Following the drawings is a complete list of electrical replacement parts for the SRL series power supplies.

6.2 ORDERING PARTS

When ordering parts from Sorensen Company, include the part number, the manufacturer part number (where applicable) and the unit model number. Address order to:

Sorensen Power Supplies
676 Island Pond Road
Manchester, New Hampshire 03103

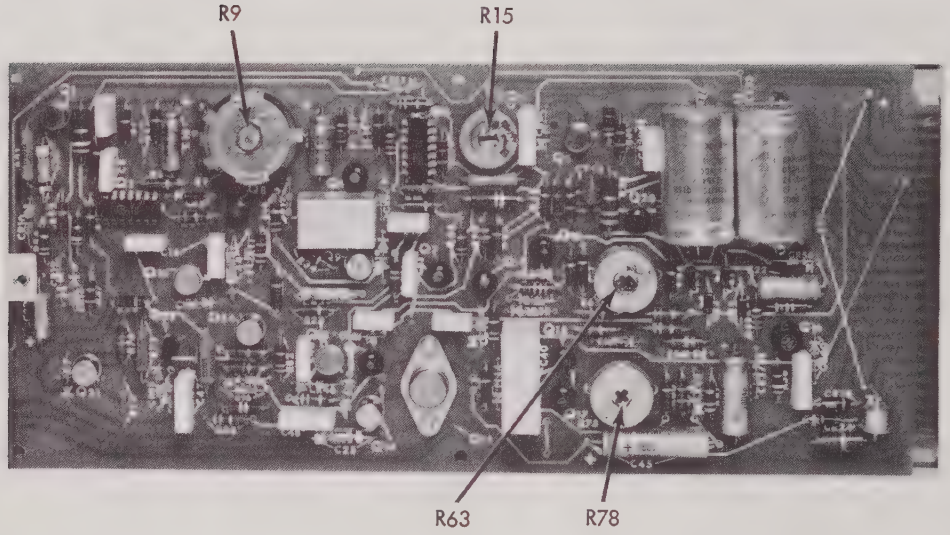


FIGURE 6-1
SRL SERIES-TYPICAL
PRINTED CIRCUIT BOARD

Notes:

1. CB 1-B used only on 10-100 and 20-50 (115 Input) of this group.
2. CR18C and D not used on 20-50, 10-50, 10-100 and indicated lead is wired to T 1-8.
3. CR26 relocated to dotted position on models 10-50, 10-100, 20-50 and 40-50.
4. R29 not used on 10-50, 10-100, 20-50, 40-50, 60-35.
5. Shunt R56 used on units 35 amp output and up.
6. CR49 inserted and indicated lead "T" used only on 40-25, 40-50, 60-17 and 60-35.
7. E1, E2 and E3 not used on models 20-50, 40-50, 60-35, and 10-100.
8. C54 used only on 10-50, 40-25 and 60-17.
9. C56 used only on 10-100 and 40-50.
10. C57 and R103 used only on 10-100, 60-35.
11. C20A and R91A used only on 20-50.
12. C33A used only on 40-50 and 10-100.
13. CR59 and R102 used only on 60-17 and 60-35.
14. C55 is 2.0MFD 200V and R101 is short circuit for model SRL 40-25
15. Add C58 and C59 for 10-50, 40-25, 60-17 only

UNIT	F2 115V	F2 210V	F2 230V
10-50	1.5A	1A	1A
10-100	8A	4A	4A
20-50	1.5A	1A	1A
40-25	1.5A	1A	1A
40-50		2A	2A
60-17	1.5A	1A	1A
60-35		1A	1A

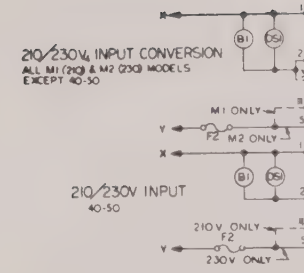
VOLTAGE CHART

MODEL	A (C23)	B (C21)	C (C26)
10-50	15.5	14	11
10-100	15.5	14	11
20-50	27.0	14	11
40-25	50.0	27	9
40-50	48.5	27	9
60-17	73.7	27	9
60-35	73.4	27	9

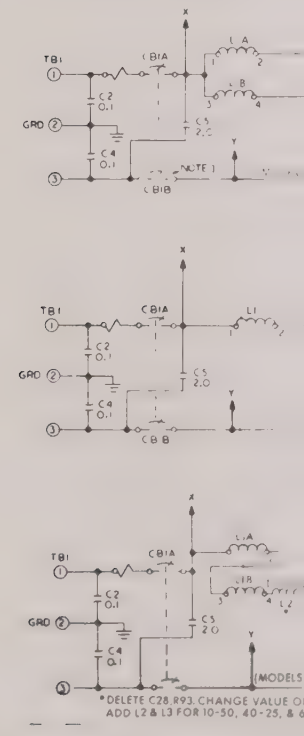
*SELECTED FOR VOLTAGE BREAKDOWN CHARACTERISTICS

UNIT	C12	C13	C 21	C 23	C24	C25	C 26	C 30	C 31	C 50	Q 9	Q 12	Q 13	Q 23	Q 24	R 17	R 29	R 30	R 40
10-50	.22	.01	15K	7 X 69K	.047	.001	9.6K	.01	6.4K	0.15	2N 697	2N 3055	2N 3771 (4)	2N 3638	2N 3638	5.36K		0	.18(8)
10-100	.22	.01	23K	8 X 85K	.047	.001	21K	.015	26K	.33	2N 697	2N 3771	2N 3771 (7)	2N 3638	2N 3638	8.66K		0	.18(14)
20-50	.1	.01	15K	7 X 26K	.01	.001	9.6K	.0033	6.7K	.33	2N 697	2N 3055	2N 3771 (5)	RCA62490	RCA62490	5.36K		0	.1(5)
40-25	.1	.01	4.7K	6 X 9.4K	.01	.001	9.6K	.0022	3.2K	0.15	2N 697*	2N 3055	2N 3055 (4)*	RCA62490	RCA62490	4.12K	2.49M	1	.18(4)
40-50	.1	.01	8.7K	6 X 21K	.01	.001	21K	.0022	5.8K	.33	2N 697*	2N 3055	2N 3055 (8)*	RCA62490	RCA62490	5.36K		0	.18(8)
60-17	.1	.01	4.7K	4 X 6.5K	.01	.001	9.6K	.001	2.5K	0.33	40321	2N 3055	2N 3442 (4)	RCA62490*	RCA62490*	3.16K	2M	1	.33(4)
60-35	.1	.01	4.7K	8 X 6.5K	.01	.001	21K	.0022	6.5K	.33	40321	2N 3055	2N 3442 (8)	RCA62490*	RCA62490*	4.12K		0	.33(8)

UNIT	R 41	R 42	R 45	R 46	R 47	R 48	R 49	R 52	R 53A	R 53B	R 55	R 56	R 62	R 63	R 65	R 66	R 77	R 85	R 89	R 92	R 103
10-50	.008	5	1.2K	1.2K	220	3	18K	12K	2K	20	.02	60A	470	1K	4.7K	5.6K	12.1K	3K	27K	150	
10-100	.0025	3	1.2K	1.2K	125	1.0	18K	20K	2K	20	.015	120A	470	1K	4.7K	5.6K	12.1K	3K	27K	150	3.3K
20-50	.008	10	1.2K	1.2K	150	2	33K	12K	4K	40	.055	60A	680	1K	12K	10K	24.9K	4K	22K	100	
40-25	.020	25 (2) ser.	2.2K	2.2K	390	10	47K	10K	8K	80	.14		820	1K	22K	18K	49.9K	8K	18K	100	
40-50	.008	50 (2) par.	2.2K	2.2K	180	5	47K	12K	8K	80	.055	60A	820	1K	22K	18K	49.9K	8K	18K	100	
60-17	.040	50 (2) ser.	2.2K	2/2K	300	15	47K	7.5K	12K	120	.185		1K	400	33K	27K	80.6K	12K	15K	100	
60-35	.015	100 (2) par.	2.2K	2.2K	150	10	47K	10K	12K	120	.120	40A	1K	400	33K	27K	80.6K	12K	15K	100	6.8K



PHASE DELAY CONTROL



DWG. E586246-REV

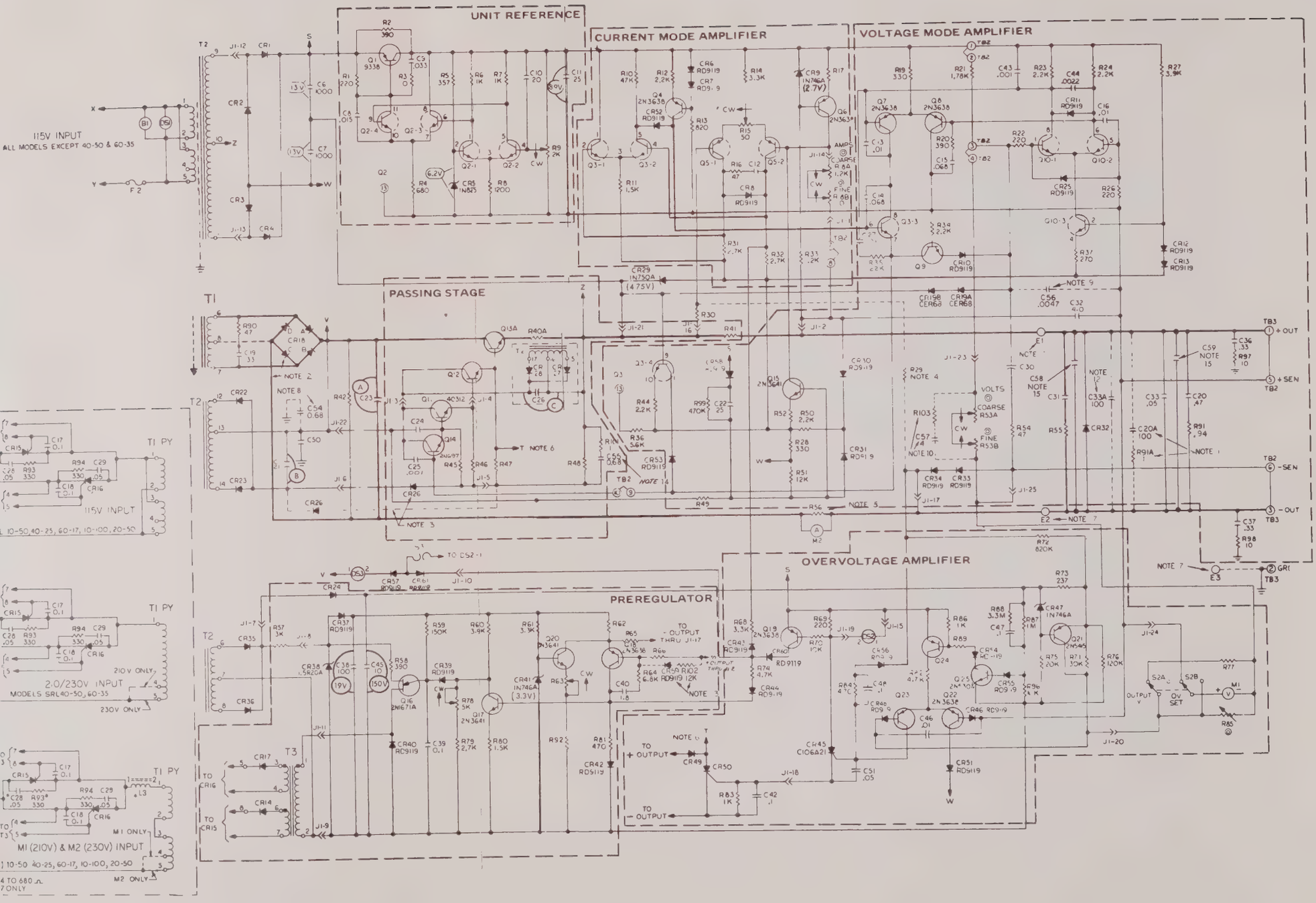
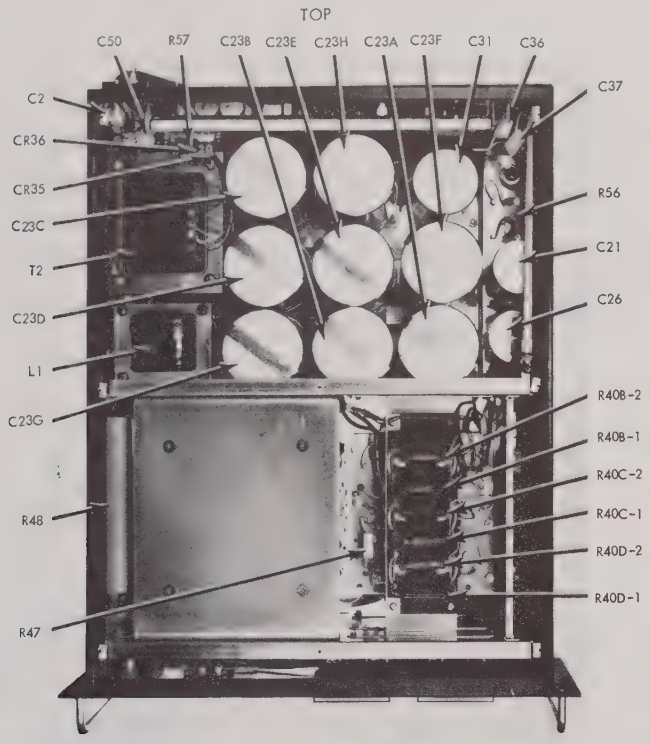
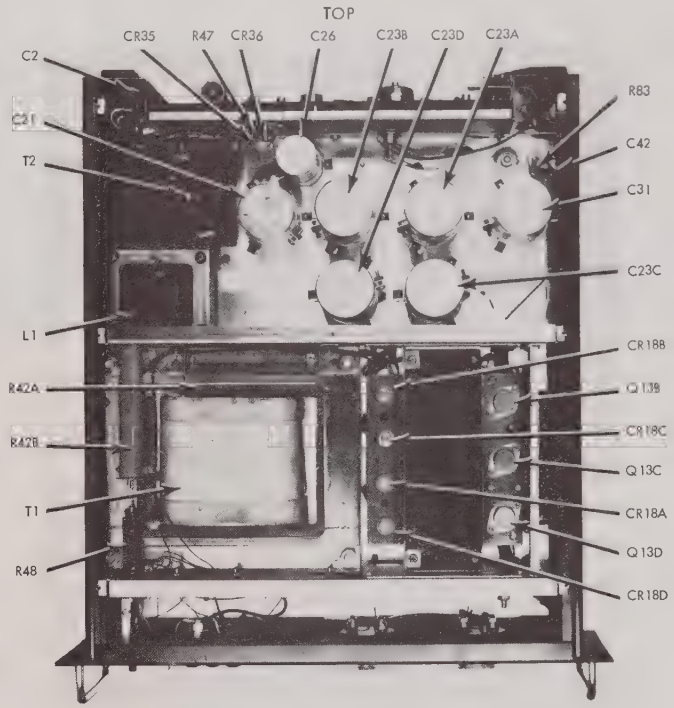


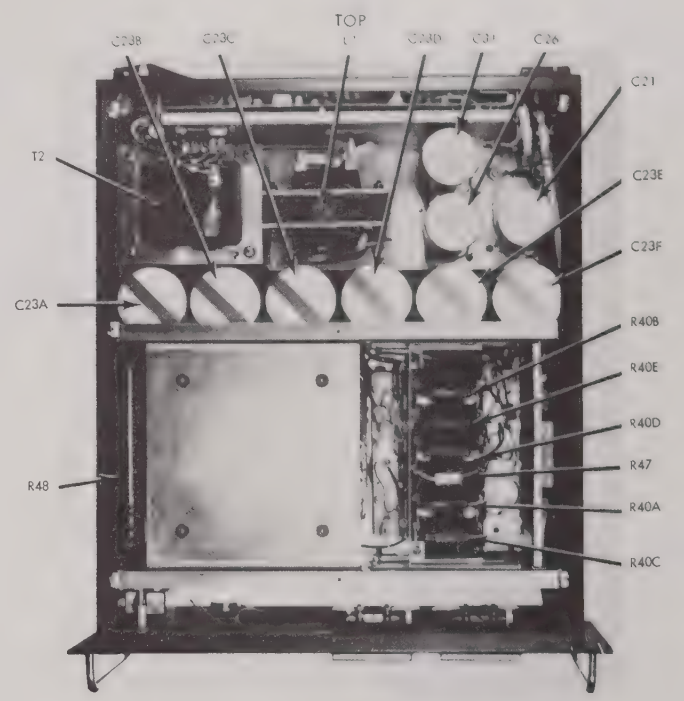
FIGURE 6-2
SCHEMATIC DIAGRAM
SRL POWER SUPPLIES



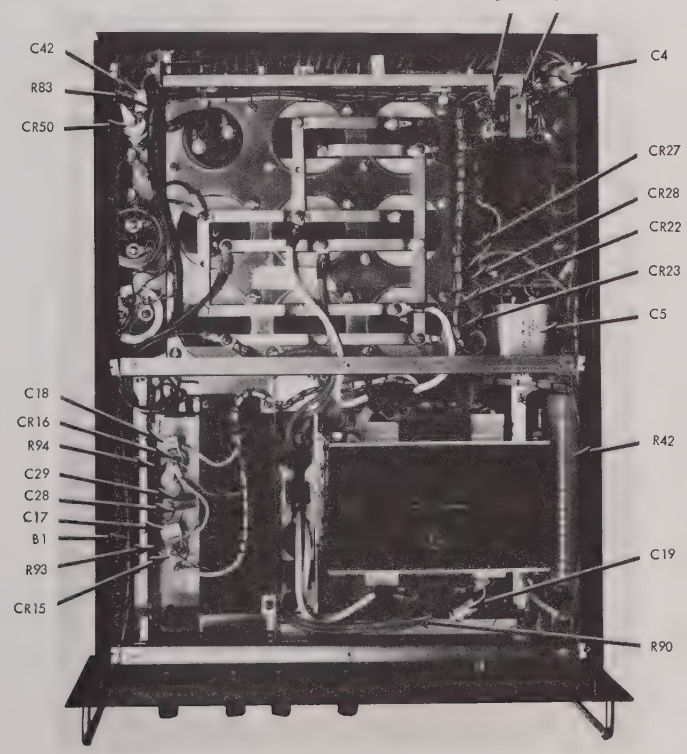
UNITS 10-50, 40-25, 10-100(SHOWN)



SRL 60-17



UNITS 20-50, 60-35, 40-50 (SHOWN)



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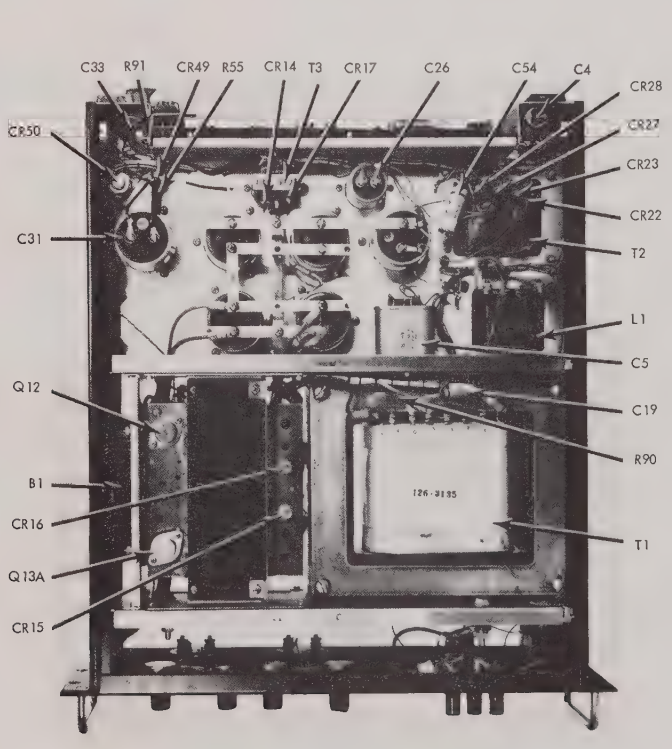

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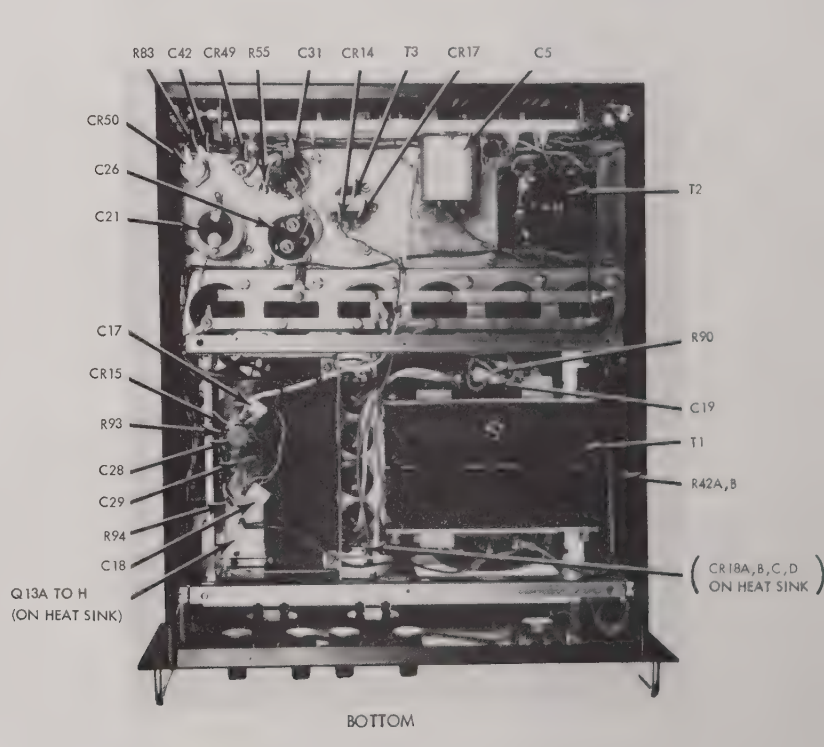

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FIGURE 6-3.
SRL - TYPICAL CHASSIS ASSEMBLIES.

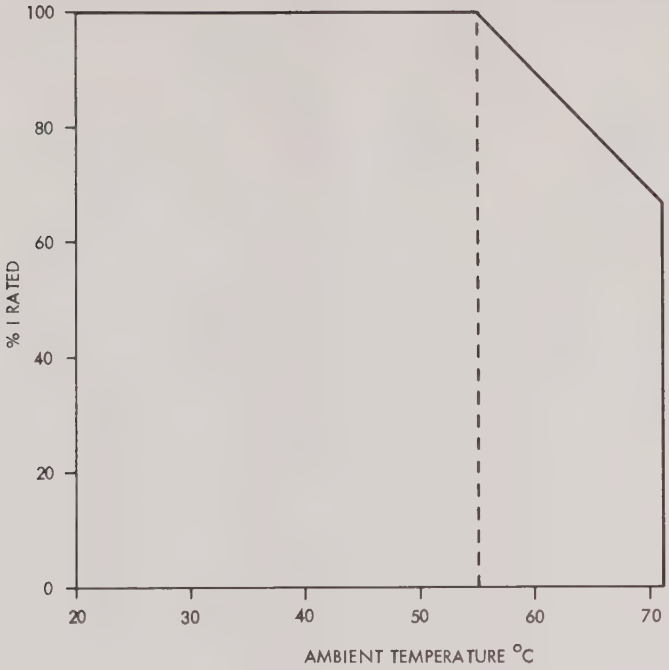

FIGURE 6-4. SRL CURRENT DERATING CHARACTERISTICS

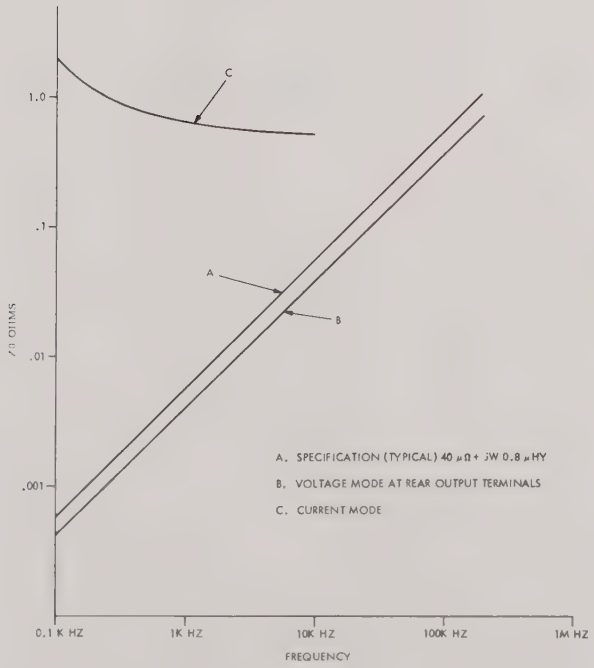

FIGURE 6-5. SRL - TYPICAL OUTPUT IMPEDANCE CURVES

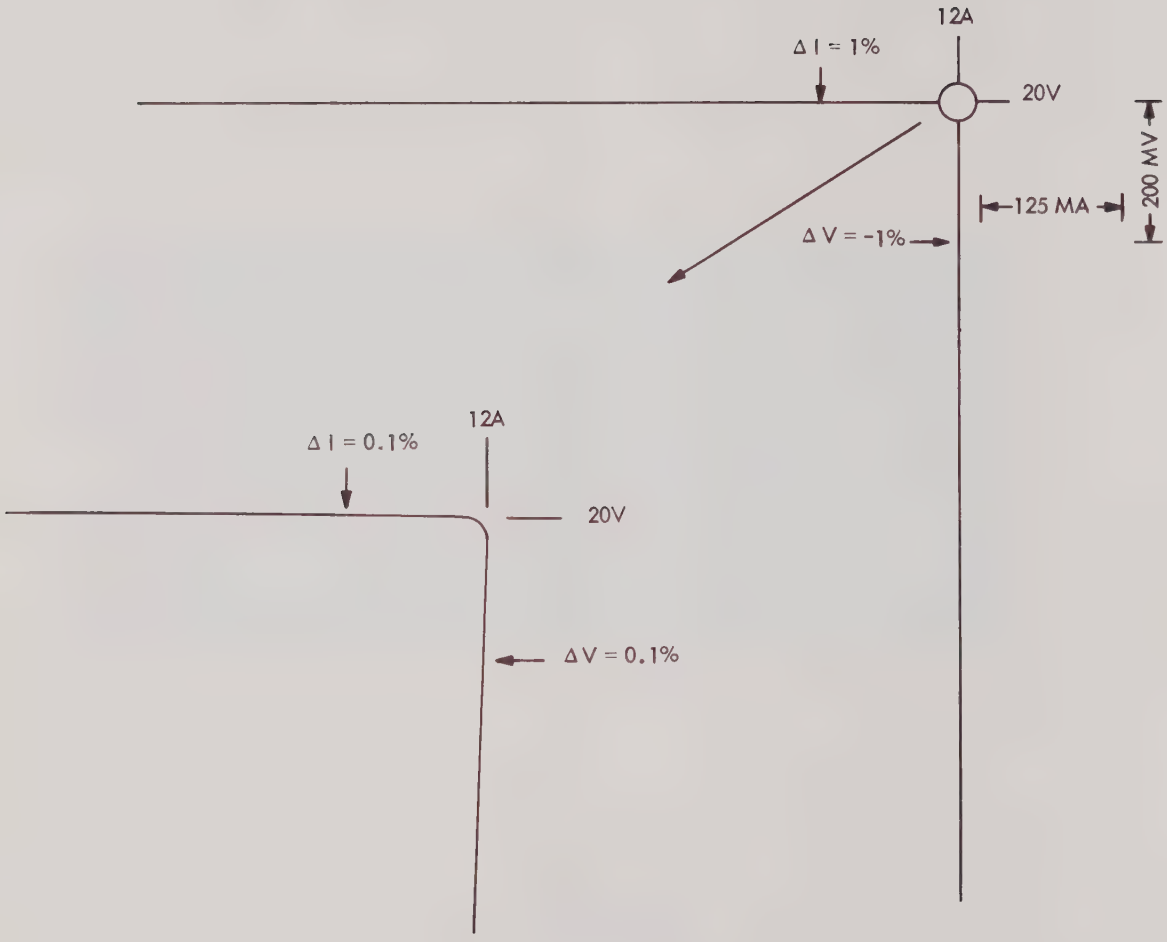

FIGURE 6-6. TYPICAL CROSSOVER CHARACTERISTICS (SRL 20-12)

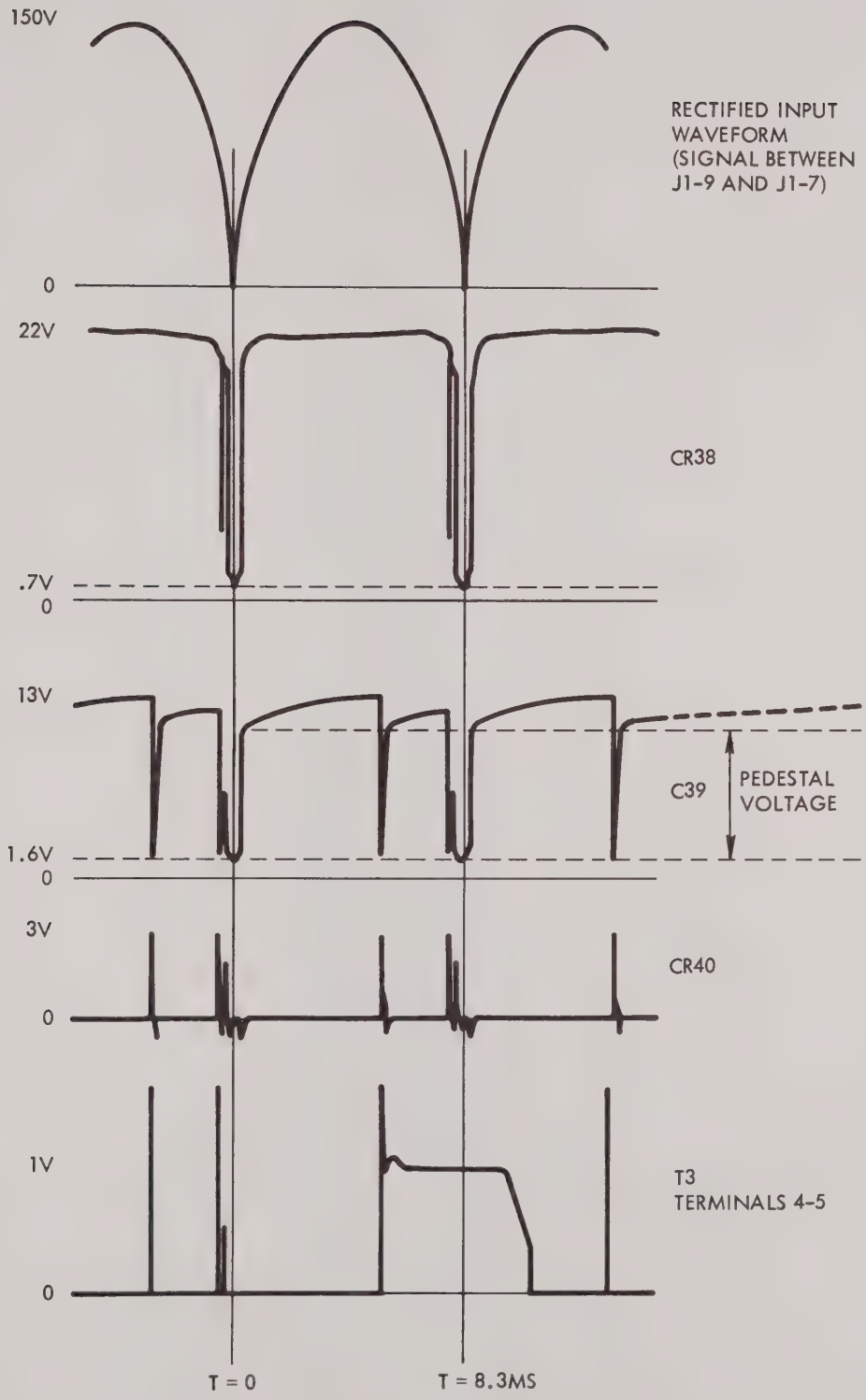

FIGURE 6-7
FIRING SECTION WAVEFORMS

SRL MODEL (FAN COOLED UNITS)

Reference Designation	10-50	10-100	20-50	40-25	40-50	60-17	60-35	DESCRIPTION	Raytheon Part No.	Manufacturer Part No.	Code
B1	x	x	x	x	x	x	x	Fan	91-1000-2		
C1,3,34,35,41,49								Capacitor, not used			
C2,4	x	x	x	x	x	x	x	Capacitor, 0.1 uF, 600V	24-2110-13		
C5	x	x	x	x	x	x	x	Capacitor, 2 uF, 330VAC	24-369		
C6,7	x	x	x	x	x	x	x	Capacitor, 1000 uF, 15V	24-2554-4		
C8	x	x	x	x	x	x	x	Capacitor, 0.015 uF, 250V	24-2015-13		
C9	x	x	x	x	x	x	x	Capacitor, 0.033 uF, 250V	24-2015-7		
C10	x	x	x	x	x	x	x	Capacitor, 20 uF, 12V	24-2276-10		
C11	x	x	x	x	x	x	x	Capacitor, 25 uF, 25V	24-2279-10		
C12	x	x						Capacitor, 0.22 uF, 250V	24-2015-17		
			x	x	x	x	x	Capacitor, 0.1 uF, 250V	24-2015-3		
C13,16,27,46	x	x	x	x	x	x	x	Capacitor, 0.01 uF, 250V	24-2015-1		
C14,15	x	x	x	x	x	x	x	Capacitor, 0.068 uF, 250V	24-2015-11		
C17,18,39,42,47, 48, 51	x	x	x	x	x	x	x	Capacitor, 0.1 uF, 250V	24-2015-13		
C19	x	x	x	x	x	x	x	Capacitor, 0.33 uF, 200V	24-2409-16		
C20	x	x	x	x	x	x	x	Capacitor, 0.47 uF, 250V	24-2015-21		
C21	x		x					Capacitor, 15K uF, 20V	24-2459-2		
		x						Capacitor, 23K uF, 20V	24-2459-4		
				x		x	x	Capacitor, 4.7K uF, 40V	24-2460-2		
					x			Capacitor, 3.7K uF, 50V	24-2445-9		
C22	x	x	x	x	x	x	x	Capacitor, 25 uF, 25VDC	24-2279-10		
C23	x							Capacitor, 69K uF, 15V (7 req'd)	24-2594-1		
		x						Capacitor, 85K uF, 20V (8 req'd)	24-2459-5		
			x					Capacitor, 26K uF, 30V (7 req'd)	24-2444-7		
				x				Capacitor, 9.4K uF, 50V (6 req'd)	24-2595-1		
					x			Capacitor, 21K uF, 50V (6 req'd)	24-2595-2		
						x	x	Capacitor, 6.5K uF, 75V (4/60-17, 8/60-35 req'd)	24-2593-1		
C24	x	x						Capacitor, 0.047 uF 250V	24-2015-9		
			x	x	x	x	x	Capacitor, 0.01 uF, 250V	24-2015-1		
C25	x	x	x	x	x	x	x	Capacitor, 0.001 uF, 200V	24-2409-1		
C26	x		x		x		x	Capacitor, 9.6K uF, 15V	24-2454-8		
		x		x		x		Capacitor, 21K uF, 15V	24-2454-3		
C28,29,33	x	x	x	x	x	x	x	Capacitor, 0.05 uF, 500V	24-2010		
C30	x							Capacitor, 0.01 uF, 250V	24-2015-1		
		x						Capacitor, 0.015 uF, 250V	24-2015-3		
			x					Capacitor, .0033 uF, 200V	24-2409-4		
				x	x			Capacitor, 0.0022 uF, 200V	24-2409-3		
						x		Capacitor, 0.001 uF, 200V	24-2409-1		
							x	Capacitor, 0.0015 uF, 200V	24-2409-2		
C31	x							Capacitor, 6.4K uF, 15V	24-2454-4		
		x						Capacitor, 69K uF, 15V	24-2594-1		
			x					Capacitor, 6.7K uF, 30V	24-2444-4		
				x				Capacitor, 3.2K uF, 40V	24-2460-1		
					x			Capacitor, 5.8K uF, 50V	24-2445-8		
						x		Capacitor, 2.5K uF, 75V	24-2525-4		
							x	Capacitor, 6.5K uF, 75V	24-2593-1		
C32	x	x	x	x	x	x	x	Capacitor, 4 uF, 25V	24-2279-4		
C36,37	x	x	x	x	x	x	x	Capacitor, 0.33 uF, 250V	24-2015-19		
C38	x	x	x	x	x	x	x	Capacitor, 100 uF, 25V	24-2279-14		
C40	x	x	x	x	x	x	x	Capacitor, 1.8 uF, 250V	24-2015-28		
C43	x	x	x	x	x	x	x	Capacitor, 0.001 uF, 200V	24-2409-1		
C44	x	x	x	x	x	x	x	Capacitor, 0.0022 uF, 200V	24-2409-3		
C45	x	x	x	x	x	x	x	Capacitor, 10 uF, 200V	24-2496		
C50	x			x				Capacitor, 0.15 uF, 400V	24-2411-14		
		x	x		x	x	x	Capacitor, 0.33 uF, 400V	24-2411-16		
C52	x							Capacitor, 2 uF, 330 VAC	24-369		
C53	x	x	x		x	x	x	Capacitor, 0.68 uF, 200V	24-2409-18		
C55				x				Capacitor, 2 uF, 200V	24-2409-21		

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Reference Designation	10-50	10-100	20-50	40-25	40-50	60-17	60-35	DESCRIPTION	Raytheon Part No.	Manufacturer Part No.	Code
CB1	x							Circuit Breaker	92-375		
		x						Circuit Breaker	92-384		
			x		x		x	Circuit Breaker	92-383		
				x		x		Circuit Breaker	92-376		
CR1,2,3,4,14,17	x	x	x	x	x	x	x	Rectifier	26-1157-2	384B	
CR5	x	x	x	x	x	x	x	Rectifier	26-205	1N825	
CR6,7,8,10,11,12,13, 19,25,30,31,33,34, 37,39,40,42,43,44, 46,48,51,52,53,54, 55,56,57,58,60	x	x	x	x	x	x	x	Rectifier	26-1017	RD9119	RT
CR41,47	x	x	x	x	x	x	x	Rectifier	26-223	1N746	HA
CR15,16	x							Rectifier	26-178-5	C30CX7	GE
		x	x		x			Rectifier	26-1159-1	C137CX77	GE
				x		x	x	Rectifier	26-1159-3	C137E	GE
		x						Rectifier	26-1164	C137CX80	GE
CR18A, B, C, D	x*							Rectifier	26-1163-3	MR1211SL	MA
		x*						Rectifier	26-1025-3	410B	
			x		x			Rectifier	26-1163-5	MR1212SL	MA
				x				Rectifier	26-820	402C	
						x	x	Rectifier	26-172	402D	
CR19A&B	x	x	x	x	x	x	x	Rectifier	26-158-1		
CR20,21								Not used			
CR22,23	x			x			x	Rectifier	26-1160-2	398B	
		x			x			Rectifier	26-173-2	368B	
						x		Rectifier	26-1157-2	384B	
			x					Rectifier	26-1006-2	MR1031A	MA
CR24,35,36	x	x	x	x	x	x	x	Rectifier	26-1157-6	384K	
CR26	x	x	x		x			Rectifier	26-173-2	368B	
				x		x	x	Rectifier	26-1006-2	MR1031A	MA
CR27,28	x		x		x			Rectifier	26-1160-2	398B	
		x						Rectifier	26-173-2	368B	
							x	Rectifier	26-1006-2	MR1031A	MA
CR29	x	x	x	x	x	x	x	Rectifier	26-211	1N750A	
CR32	x			x	x	x	x	Rectifier	26-1077-1	ST410P	ST
		x						Rectifier	26-996	402B	
CR38	x	x	x	x	x	x	x	Rectifier	26-244		
CR45	x	x	x	x	x	x	x	Rectifier	26-1105	C106A21	GE
CR49				x	x	x	x	Rectifier	26-996	402B	
CR50	x	x						Rectifier	26-1161-1	C45U	GE
			x					Rectifier	26-1161-2	C45F	GE
				x	x	x	x	Rectifier	26-1161-3	C45A	GE
CR9&Q6	x		x	x	x	x	x	Matched Set	585036-3		
		x						Matched Set	585036-4		
DS1	x	x	x	x	x	x	x	Indicator Light	43-357		
DS2,3	x	x	x	x	x	x	x	Indicator Light	43-358		
L1	x							RFI Choke	127-1849		
		x	x	x		x		RFI Choke	127-1847		
					x		x	RFI Choke	127-1851		
*M1	x	x						Voltmeter, 0-12	94-579-1		
			x					Voltmeter, 0-25	94-579-2		
				x	x			Voltmeter, 0-50	94-579-3		
						x	x	Voltmeter, 0-80	94-579-4		
*M2	x		x		x			Ammeter, 0-60	94-462-8		
				x				Ammeter, 0-30	94-462-6		
		x						Ammeter, 0-120	94-462-9		
						x		Ammeter, 0-20	94-462-5		
							x	Ammeter, 0-40	94-462-7		
Q1	x	x	x	x	x	x	x	Transistor	18-146	RT9338	RT
Q2,3	x	x	x	x	x	x	x	Transistor, Multiple Package	18-605	CA3046	RCA
Q4,7,8,18,19,22 23,24	x	x	x	x	x	x	x	Transistor	18-143	2N3638	
Q5	x	x	x	x	x	x	x	Transistor, Dual	18-176		
Q9	x	x	x					Transistor	18-115	2N697	
				x	x			Transistor	18-161-3		
						x	x	Transistor	18-165	40321	

*CR18C, D not used on Models 10-50 or 10-100, R20-50

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Reference Designation	10-50	10-100	20-50	40-25	40-50	60-17	60-35	DESCRIPTION	Raytheon Part No.	Manufacturer Part No.	Code
Q10	x	x	x	x	x	x	x	Transistor, Multiple Package	18-606	CA3053	RCA
Q11	x	x	x	x	x	x	x	Transistor	18-142	40312	
Q12	x		x	x	x	x	x	Transistor	18-151	2N3055	
		x						Transistor	18-202	2N3771	
Q13	4	7	5					Transistor	18-202	2N3771	
				4	8			Transistor	18-178-1	2N3055	
						4	8	Transistor	18-163	2N3442	
Q14	x	x	x	x	x	x	x	Transistor	18-115	2N697	
Q15,17,20	x	x	x	x	x	x	x	Transistor	18-144	2N3641	
Q16	x	x	x	x	x	x	x	Transistor	18-097	2N1671A	
Q21	x	x	x	x	x	x	x	Transistor	18-216	2N5415	RCA
Q25	x	x	x	x	x	x	x	Transistor	18-214	2N5307	
R1,22,26,69	x	x	x	x	x	x	x	Resistor, 220 Ω , 1/2W ±10%	27-101		
R2	x	x	x	x	x	x	x	Resistor, 390 Ω , 1W ±10%	28-703		
R3,97,98	x	x	x	x	x	x	x	Resistor, 10 Ω , 1/2W ±10%	27-180		
R4	x	x	x	x	x	x	x	Resistor, 680 Ω , 1/2W ±10%	27-156		
R5	x	x	x	x	x	x	x	Resistor, 357 Ω , 1/8W ±1%	28-1285	CEA-TO	
R6,7,86,83	x	x	x	x	x	x	x	Resistor, 1.0KΩ , 1/2W ±10%	27-103		
R8,33,46	x	x	x	x	x	x	x	Resistor, 1.2KΩ , 1/2W ±10%	27-1110		
R9	x	x	x	x	x	x	x	Potentiometer, 2KΩ , 2W ±10%	29-519		
R10	x	x	x	x	x	x	x	Resistor, 47KΩ , 1/2W ±10%	27-112		
R11,80	x	x	x	x	x	x	x	Resistor, 1.5K Ω , 1/2W ±10%	27-171		
R12,23,24,34,44 50,95	x	x	x	x	x	x	x	Resistor, 2.2K Ω , 1/2W ±10%	27-152		
R13	x	x	x	x	x	x	x	Resistor, 820 Ω , 1/2W ±10%	27-182		
R14,61,68	x	x	x	x	x	x	x	Resistor, 3.3K Ω , 1/2W ±10%	27-140		
R15	x	x	x	x	x	x	x	Potentiometer, 50Ω	29-522		
R16,90,54	x	x	x	x	x	x	x	Resistor, 47 Ω , 1/2W ±10%	27-181		
R17	x		x		x			Resistor, 5.36K Ω , 1/8W ±1%	28-1413	CEA-T2	
		x						Resistor, 8.55K Ω , 1/8W ±1%	28-1414	CEA-T2	
				x			x	Resistor, 4.12K Ω , 1/8W ±1%	28-1417	CEA-T2	
					x			Resistor, 3.16K Ω , 1/8W ±1%	28-1416	CEA-T2	
R18A	x	x	x	x	x	x	x	Potentiometer, 1.2K Ω , 2W -0+10%	29-596		
R18B	x	x	x	x	x	x	x	Potentiometer, 10 Ω , 2W ±10%	29-595		
R19	x	x	x	x	x	x	x	Resistor, 330 Ω , 1/2W ±10%	27-102		
R20,58	x	x	x	x	x	x	x	Resistor, 390 Ω , 1/2W ±10%	27-1109		
R21	x	x	x	x	x	x	x	Resistor, 1.78KΩ , 1/2W ±1%	28-1373	CEC T2	
R27	x	x	x	x	x	x	x	Resistor, 3.9K Ω , 1/2W ±10%	27-186		
R28	x	x	x	x	x	x	x	Resistor, 330 Ω , 1W ±10%	27-291		
R29					x			Resistor, 2.49 meg Ω, 1/2W ±1%	28-1396	CEC TO	
						x		Resistor, 2 meg Ω, 1/2W ±1%	28-1399	CEC TO	
R30						x		Resistor, 1 Ω, 1/2W ±10%	27-983		IRC
R31,32	x	x	x	x	x	x	x	Resistor, 2.7K Ω , 1/2W ±10%	27-174		
R35	x	x	x	x	x	x	x	Resistor, 22K Ω , 1/2W ±10%	27-142		
R36	x	x	x	x	x	x	x	Resistor, 5.6K Ω , 1/2W ±10%	27-1112		
R37	x	x	x	x	x	x	x	Resistor, 270 Ω , 1/2W ±10%	27-191		
R38								Not used			
R39								Not used			
R40	8	14	4	8				Resistor, .18 Ω , 12.5W ±5%	27-590-7		
			x					Resistor, .1 Ω , 12.5W ±5%	27-590-1		
					4	8		Resistor, .33 Ω , 12.5W ±5%	27-590-13		

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Reference Designation	10-50	10-100	20-50	40-25	40-50	60-17	60-35	DESCRIPTION	Raytheon Part No.	Manufacturer Part No.	Code
R41	x							Resistor, 8 meg	190-4159		
		x						Resistor, 2.5 meg	190-4165		
			x		x			Resistor, 8 meg	190-4178		
				x				Resistor, 20 meg	190-4140		
						x		Resistor, 40 meg	190-4141		
							x	Resistor, 15 meg	190-4179		
R42	x							Resistor, 5 Ω , 100W	27-827		
		x						Resistor, 3 Ω , 100W	27-1010		
			x					Resistor, 10 Ω , 100W	27-867		
				2				Resistor, 25 Ω , 50W (Series)	27-809		
					2			Resistor, 50 Ω , 100W (Parallel)	27-856		
						2		Resistor, 50 Ω , 50W (Series)	27-841		
							2	Resistor, 100 Ω , 100W (Parallel)	27-1009		
R43								Not used			
R45,46	x	x	x		x	x	x	Resistor, 1.2K Ω , 1/2W ±10%	27-1110		
				x				Resistor, 2.2K Ω , 1/2W ±10%	27-152		
R47	x							Resistor, 220 Ω , 2W ±10%	27-363		
		x						Resistor, 125 Ω , 5W ±10%	28-557		
			x					Resistor, 150 Ω , 2W ±10%	27-341		
				x				Resistor, 390 Ω , 2W ±10%	27-364		
					x			Resistor, 180 Ω , 5W ±10%	27-499-18		
						x		Resistor, 300 Ω , 2W ±5%	27-1137		
							x	Resistor, 150 Ω , 5W ±10%	27-499-17		
R48	x							Resistor, 3 Ω , 50W	27-805		
		x						Resistor, 1 Ω , 100W	27-826		
			x					Resistor, 2 Ω , 50W	27-804		
				x			x	Resistor, 10 Ω , 50W	27-850		
					x			Resistor, 5 Ω , 100W	27-827		
						x		Resistor, 15 Ω , 25W	27-744		
R49	x	x						Resistor, 18K Ω , 1/2W ±10%	27-1119		
			x					Resistor, 33K Ω , 1/2W ±10%	27-163		
				x	x	x	x	Resistor, 47K Ω , 1/2W ±10%	27-112		
R51	x	x	x	x	x	x	x	Resistor, 12K Ω , 1/2W ±10%	27-1108		
R52	x		x		x			Resistor, 12K Ω , 1/2W ±10%	27-1108		
		x						Resistor, 20K Ω , 1/2W ±10%	27-134		
				x			x	Resistor, 10K Ω , 1/2W ±10%	27-133		
						x		Resistor, 7.5K Ω , 1/2W ±10%	27-1181		
R53A	x	x						Potentiometer, 2K Ω , 2W + 20, -0%	29-587		
			x					Potentiometer, 4K Ω , 2W + 20, -0%	29-588		
				x	x			Potentiometer, 8K Ω , 2W + 20, -0%	29-589		
						x	x	Potentiometer, 12K Ω , 2W+ 20, -0%	29-590		
R53B	x	x						Potentiometer, 20 Ω , 2W ±10%	29-591		
			x					Potentiometer, 40 Ω , 2W ±10%	29-592		
				x	x			Potentiometer, 80 Ω , 2W ±10%	29-593		
						x	x	Potentiometer, 120 Ω , 2W ±10%	29-594		
R55	x							Resistor, 0.02 Ω	190-4160		
			x		x		x	Resistor, 0.55 Ω	190-4180		
				x				Resistor, 0.14 Ω	190-4161		
						x		Resistor, 0.185 Ω	190-4162		
R56	x		x		x			Shunt, 60A	94-048		
		x						Shunt, 120A	94-047		
							x	Shunt, 40A	94-049		
R57	x	x	x	x	x	x	x	Resistor, 3K Ω , 7W	27-471-9		WL
R59	x	x	x	x	x	x	x	Resistor, 150KΩ , 1/2W ±10%	27-119		
R60	x	x	x	x	x	x	x	Resistor, 3.9KΩ , 1/2W ±10%	27-186		
R62	x	x						Resistor, 470 Ω , 1/2W ±10%	27-166		
			x					Resistor, 680 Ω , 1/2W ±10%	27-156		
				x	x			Resistor, 820 Ω , 1/2W ±10%	27-182		
						x	x	Resistor, 1K Ω , 1/2W ±10%	27-103		
R63	x	x	x	x	x			Potentiometer, 1K Ω, 2W	29-503		
						x	x	Potentiometer, 400Ω, 2W	29-547		
R64	x	x	x	x	x	x	x	Resistor, 6.8KΩ , 1/2W ±10%	27-185		
R65	x	x						Resistor, 4.7KΩ , 1/2W ±10%	27-107		
			≡					Resistor, 12K Ω , 1/2W ±10%	27-1108		
				x	x			Resistor, 22K Ω , 1/2W ±10%	27-142		
						x	x	Resistor, 33K Ω , 1/2W ±10%	27-163		
R66	x	x						Resistor, 5.6KΩ , 1/2W ±10%	27-1112		
			x					Resistor, 10K Ω , 1/2W ±10%	27-133		
				x	x			Resistor, 18K Ω , 1/2W ±10%	27-1119		
						x	x	Resistor, 22K Ω , 1/2W ±10%	27-110		
R67								Not used			
R70	x	x	x	x	x	x	x	Resistor, 10KΩ , 1/2W ±10%	27-133		
R71	x	x	x	x	x	x	x	Resistor, 30KΩ , 1/2W ±10%	27-398-24		
R72	x	x	x	x	x	x	x	Resistor, 820KΩ , 1/2W ±10%	27-1177		

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Reference Designation	10-50	10-100	20-50	40-25	40-50	60-17	60-35	DESCRIPTION	Raytheon Part No.	Manufacturer Part No.	Code
R73	x	x	x	x	x	x	x	Resistor, 237 Ω, 1/8W ±1%	28-1419	CEA-TO	
R74,82	x	x	x	x	x	x	x	Resistor, 4.7KΩ , 1/2W ±10%	27-107		
R75	x	x	x	x	x	x	x	Resistor, 20KΩ , 3W	27-398-25		
R76	x	x	x	x	x	x	x	Resistor 120KΩ , 1/2W ±10%	27-1179		
R77	x	x						Resistor, 12.1KΩ , 1/2W ±1%	28-1408	CEC-TO	
			x					Resistor, 24.9KΩ , 1/2W ±1%	28-1261	CEC-TO	
				x	x			Resistor, 49.9KΩ , 1/2W ±1%	28-1409	CEC-TO	
						x	x	Resistor, 80.6KΩ , 1/2W ±1%	28-1351	CEC-TO	
R78	x	x	x	x	x	x	x	Potentiometer, 5K Ω, 2W	29-426		
R79	x	x	x	x	x	x	x	Resistor, 2.7K Ω , 1/2W ±10%	27-174		
R81,84	x	x	x	x	x	x	x	Resistor 470 Ω . 1/2W ±10%	27-166		
R85	x	x						Potentiometer, 3K Ω , 2W ±10%	29-597		
			x					Potentiometer, 4K Ω , 2W ±10%	29-598		
				x	x			Potentiometer, 8K Ω , 2W ±10%	29-599		
						x	x	Potentiometer, 12K Ω , 2W ±10%	29-600		
R87	x	x	x	x	x	x	x	Resistor 1.0 meg Ω, 1/4W ±1%	28-1418	CEC-TO	
R88	x	x	x	x	x	x	x	Resistor, 3.3 meg Ω, 1/2W ±10%	27-162		
R89	x	x						Resistor, 27KΩ , 1/2W ±10%	27-110		
			x					Resistor, 22KΩ , 1/2W ±10%	27-142		
				x	x			Resistor, 18KΩ , 1/2W ±10%	27-1119		
						x	x	Resistor, 15KΩ , 1/2W ±10%	27-179		
R91	x	x	x	x	x	x	x	Resistor, 0.24 Ω , 2W ±5%	28-1252		
R92	x	x						Resistor, 150 Ω , 1/2W ±10%	27-183		
			x	x	x	x	x	Resistor, 100 Ω , 1/2W ±10%	27-173		
R93,94	x	x	x	x	x	x	x	Resistor, 330 Ω , 1/2W	27-178		
R96	x	x	x	x	x	x	x	Resistor, 10K Ω, 1/4W ±1%	28-1325	CEA-TO	
R99	x	x	x	x	x	x	x	Resistor, 470KΩ , 1/2W ±10%	27-146		
R101				x		x		Resistor, 1 Ω, 1/2W			
R103		X					X	Resistor, 3.3 K Resistor, 6.8 K			
S2	x	x	x	x	x	x	x	Switch	45-168		
S3	x	x	x	x	x	x	x	Thermostat	92-516		
T1	x							Transformer, Rect. Input	126-3133		
		x						Transformer, Rect. Input	126-3144		
			x					Transformer, Rect. Input	126-3145		
				x				Transformer, Rect. Input	126-3134		
					x			Transformer, Rect. Input	126-3146-1		
						x		Transformer, Rect. Input	126-3135		
							x	Transformer, Rect. Input	126-3146-2		
T2	x		x					Transformer Control	126-3132		
		x						Transformer Control	126-3147-1		
				x	x	x	x	Transformer Control	126-3131		
					x			Transformer Control	126-3147-2		
T3	x	x	x	x	x	x	x	Transformer Pulses	126-3123		

WARRANTY

Sorensen Company warrants all parts of equipment of its manufacture, except special purpose tubes and semi-conductor devices which carry their own manufacturer's warranty, to be free from defects caused by faulty material or poor workmanship. Sorensen Company warrants its products to conform to applicable commercial or military specifications when confirmed on the Order Acknowledgment form to be free from defects caused by faulty material or poor workmanship. Sorensen Company's obligation is limited under the warranty to repair or replacement of products in kind, or at its sole option to issuance of a credit of original purchase price. Returns must be accompanied by a Sorensen Company Return Authorization form and conform to standard conditions for adjustment. The aforesaid warranty shall expire twelve (12) months following the last day of the month of shipment from Sorensen Company's plant. The foregoing states the entire warranty extended by Sorensen Company. No other warranty, expressed or implied, is made and, specifically, Sorensen Company makes no warranty of merchantability or fitness for any purpose. In no case shall Sorensen Company be liable for any special or consequential damages. Authorization must be obtained prior to return of defective items.

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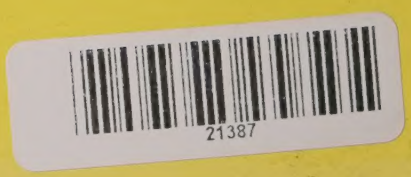

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